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INSTRUCTION MANUAL

FOR

MODEL PB-1 VF LINE ANALYZER

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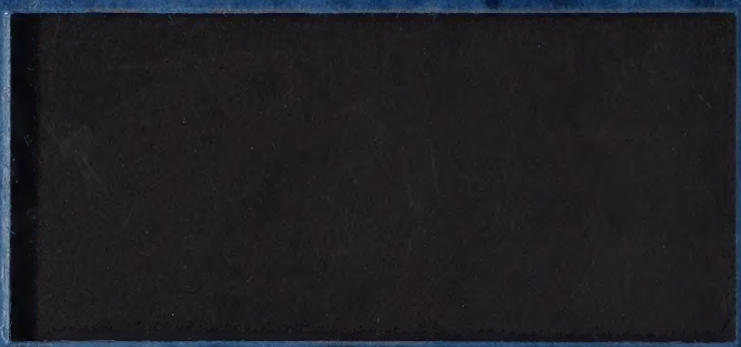

INSTRUCTION MANUAL

FOR

MODEL PB-1 VF LINE ANALYZER

BRADLEY TELCOM CORP.
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GENERAL INFORMATION

1-1. INTRODUCTION

1-2. The PB-1 VF Line Analyzer employs a new method of detecting, analyzing, displaying, identifying and measuring disturbances induced on signals by impairments of the voice-frequency channels through which those signals are transmitted. The new method is called Suppressed-Tone Phasor Representation.

1-3. This manual covers theory, operation, and alignment of the PB-1 VF Line Analyzer, and interpretation of data displayed by the instrument.

a. Section I of this manual describes the new Suppressed-Tone Phasor Representation method, defines the various kinds of disturbances and impairments, and explains how the PB-1 permits identification and measurement of each type of disturbance, even in complex combinations of disturbances.

b. The Brochure at the end of Section I contains supplementary information and useful reference data. The illustrations of PB-1 displays on Pages 6 through 9 of the Brochure represent a valuable catalog of displays corresponding to various combinations of known and specified disturbances. Those illustrations may be used to analyze actual PB-1 displays and identify the disturbances causing them.

c. Appendix A to this manual describes a procedure, employing the Bradley Telcom Model 2A/2B Line Simulator as a signal source for the PB-1 VF Line Analyzer, to familiarize personnel with the use of the PB-1 for analysis, identification, and measurement of the various kinds of disturbances.

1-4. DIGITAL DATA TRANSMISSION OVER TELEPHONE CHANNELS

1-5. The phenomenal growth of automatic data processing and digital computation since 1950 has been accompanied by increased use of common carrier switched telephone networks for transmission of digital data between subscribers. To facilitate such transmission, interfacing equipment (called data sets, subsets, modems, etc.) was developed to connect the digital equipment at each end to the telephone network. A modulator at the transmitting end accepts baseband digital (and sometimes analog) data from a computer, processor, or memory device, and converts that baseband data into a form suitable for transmission

over telephone channels. A demodulator at the receiving end converts the modulated data received from the telephone channel back to base-band data for computation, processing or storage. For two-way transmission, a modulator and demodulator are required at each end, and the combined equipment is therefore called a modem.

1-6. Significant problems frequently arise in the transmission of digital data over telephone channels, and those problems increase greatly with the rate of digital data transmission. Such problems arise because the switched telephone network was designed primarily for voice communications, and not for transmission of digital data. The original design criteria were derived mainly from human physiological data such as speech and hearing characteristics, and from subjective data such as user habits and preferences. The performance characteristics of the voice-frequency channels of the telephone network are thus optimized for transmission of the particular type of analog signal known as speech, but are not optimized for transmission of digital signals. Moreover, certain types of equipment, such as compandors and echo suppressors, that are provided in the telephone network to improve voice communications, may even cause problems when that network is used for digital signal transmission.

1-7. When subscribers use data sets or modems supplied by common carriers, to transmit and receive data over common carrier telephone facilities, the major responsibility for solving any data transmission problems is obviously that of the carriers. However, when subscribers use modems not supplied by common carriers, to transmit data over common carrier telephone facilities, the responsibilities for data transmission problems may not be so clear. Such problems may arise because of deficiencies in the modems, in the facilities, or in both. It then becomes necessary for both subscribers and common carriers to be able to test the telephone network facilities, in order to determine the sources of problems. Such testing must be made not only against voice transmission criteria, but also against data transmission criteria.

1-8. TESTING OF VOICE AND DATA TRANSMISSION FACILITIES

1-9. Telephone channel performance is traditionally defined in terms of relatively static analog parameters such as loss, frequency response, envelope delay, and nonlinear distortion. Those static parameters are reasonably related to the voice-frequency-transmission performance of telephone channels, but they are not adequately related to the data-transmission performance of those channels, especially at high rates of transmission. The specification of telephone channels for data transmission requires not only the static parameters, but a number of dynamic parameters that have not yet been defined or have been inadequately defined. In order to define and specify such dynamic parameters, they

must be measured; but most of the equipment used for the measurement of static parameters is unable to measure the dynamic parameters that affect data transmission. The measurement of those dynamic parameters requires instrumentation that is capable of detecting and identifying small instantaneous disturbances in the presence of much larger signals, and of separating and measuring each of those small disturbances. This is the inverse of the operational problem of identifying the signal while ignoring the disturbance. The following discussion is concerned with detecting these latter impairments in analog communication channels and classifying them for diagnostic and maintenance purposes.

1-10. Telephone network transmission channels perform differently when loaded and when idle. Since only channels loaded with data can induce disturbances on that data, they are preferably tested in the loaded condition. One method of loading a channel for testing is to transmit a 'holding' tone through that channel. The Model PB-1 VF Line Analyzer utilizes such tones as test tones, and monitors the received tones (i.e., after transmission through channels under test) for disturbances induced on those tones by channel impairments. There are two basic methods of testing a transmission channel; one-way testing, and loopback testing. Figure 1-1 shows the basic configuration for one-way testing of a telephone transmission facility, and Figure 1-2 shows the configuration for loopback testing. Various types of disturbances that can be induced on a test tone are shown in Figure 1-1. Harmonic distortion is introduced only at the terminals, because harmonics occurring after the channel has been multiplexed will fall out of band. Although not shown in Figure 1-2, the disturbances shown in Figure 1-1 can be introduced into both the transmit and receive channels of a loopback connection. One-way testing detects disturbances in one direction, and loopback testing detects the sum of the disturbances in both directions. In loopback testing, some disturbances may be introduced equally and oppositely in each direction, and thus cancel out. Thus, though loopback testing may be more convenient, the results of such testing should be confirmed if possible, by one-way testing in at least one of the two directions, to ascertain that there are no significant one-way impairments that have been canceled out by looping back.

1-11. The PB-1 is a transmission line analyzer that detects and displays in-phase and quadrature components of line disturbances normalized relative to a sinusoidal test tone, either at the test tone frequency, or at its second or third harmonics. Information is thus provided which is not available from time-domain or conventional frequency-domain measurement techniques; and which can be obtained only partially by large-scale Fast-Fourier Transform analyzer equipment even when such equipment is fully complemented with input and output adapters. The PB-1 does not replace existing types of measuring equipment for making 'boiler plate' measurements required by tariff considerations, as in turning up a facility. It does, however, offer a new capability for initial inspection and subsequent trouble shooting of data transmission facilities.

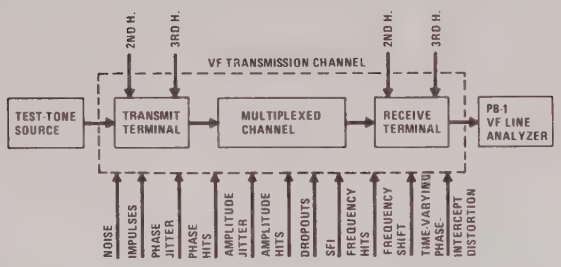

Figure 1-1 One-Way Facility Testing

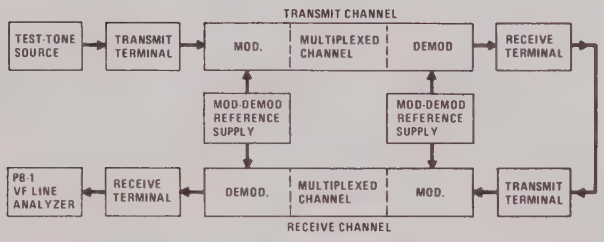

Figure 1-2 Loopback Facility Testing

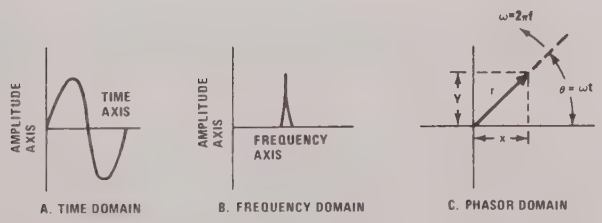

Figure 1-3 Representations of a Sinusoidal Tone

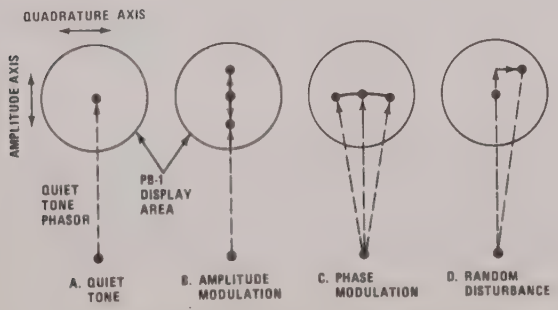

Figure 1-4 Suppressed-Tone Phasor Representation

1-12. The PB-1 views the disturbances induced on a test tone by a transmission channel in the same way that synchronous modem receivers view the same disturbances induced on data streams (i.e., in the quadrature-amplitude plane, and on an instantaneous peak basis. Conventional notched noise measurements are rms and are phase-insensitive, thus ignoring both the phase-error sensitivity of synchronous modems and the crest factors of channel noise.). As a result, the PB-1 is capable of evaluating and comparing data transmission facilities in a matter of minutes. The instrument then determines, by inspection of the disturbances induced on a standard test tone, whether or not the facility will pass data with specific modems. Appendix B to this manual describes how the 'go' and 'no-go' criteria are established.

1-13. Because it sees the same line impairments that synchronous modems do, the PB-1 is a powerful tool for facility design and production testing as well as for the evaluation and comparison of facilities by potential users. It is the fastest way to measure many impairments, and the only way to see certain problems. In fact the existence of certain previously unclassified line impairments has only become apparent upon examination, with the PB-1, of channels which meet all measurement performance criteria but which will not pass data. Five minutes on a facility is enough to classify its steady-state data transmission characteristics. A few hours spent exercising competing facilities and equipments, prior to a selection commitment, can eliminate years of subsequent data transmission problems. Such large differences exist between PCM and FDM systems, between successive generations of the same manufacturer's equipment and between equipment of different manufacturers, that it is remarkable that synchronous data moves at all through tandem systems of different manufacture.

1-14. SUPPRESSED-TONE PHASOR-DOMAIN MEASUREMENTS

1-15. Signals are conventionally represented in the time domain (Figure 1-3A), as displayed by oscilloscopes, and in the frequency domain (Figure 1-3B), as displayed by spectrum analyzers. Signals may also be represented in the phasor domain (Figure 1-3C), and displayed on suitable instruments such as the PB-1 VF Line Analyzer.

1-16. Suppressed-Tone Phasor-Domain Representation is a new technique for rapid display, classification, identification, and measurement of all disturbances induced on a test tone by a transmission channel.

1-17. In the phasor domain, a sinusoid of frequency f(Hz) is represented by a radius vector called a phasor, which hypothetically rotates about its origin at the angular velocity $w(=2\pi f)$ radians per second (Figure 1-3C), but which appears stationary because it is 'illuminated' at exactly the same position in each rotation by a hypothetical stroboscope. The amplitude

of the sinusoid is represented by the length of the phasor, and the phase of the sinusoid is represented by the angular position of the phasor (with respect to a 0^{o} angle reference) at the instant of 'illumination'. One common 0^{o} angle reference for phasors is the horizontal to the right of the origin, as in Figure 1-3C; another, used by the PB-1, is the vertical up from the origin, as in Figure 1-4A. Note that a phasor may be represented either by the polar coordinates r(length) and θ(angle with respect to the 0^{o} reference), or by the rectangular coordinates r cos θ and r sin θ which represent the projections or 'shadows' of the phasor on the in-phase axis and on the quadrature axis respectively. Each 'shadow' describes the familiar time-domain sine wave; as the phasor rotates through 360^{o}, the sine and cosine each goes through a complete cycle.

1-18. When a pure sinusoidal test tone is transmitted through a voice-frequency communication channel, impairments in the channel may induce on that tone a wide range of disturbances such as noise, phase modulation, amplitude modulation, interfering tones, harmonics resulting from non-linear distortion, and transients of various kinds. If the steady-state component of the received signal (i.e., the 'quiet tone') is displayed as a vertical phasor (Figure 1-4A), the disturbances (which are not stationary with respect to the tone) will add (vectorially, and on an instantaneous basis) to the tip of that phasor, producing a resultant phasor. Since disturbances are usually much smaller in amplitude than the test tone, the tip of the resultant phasor (representing the vector sum of the quiet tone plus instantaneous disturbances) is normally confined to a small area around the tip of the quiet-tone phasor. This is the area that is displayed by the PB-1 in its VECTOR NOTCH mode. By suppressing the quiet-tone phasor (which contains no information about disturbances) so that the tip of that phasor is at the center of the display, the PB-1 shows only the disturbance phasors. These can therefore be shown on a greatly enlarged scale, thus increasing the resolution and accuracy with which those disturbances can be measured.

1-19. The direction and amplitude of the disturbance phasors on the suppressed-tone phasor display depend on the nature and amplitude of the disturbances.

a. Tone-correlated amplitude disturbances such as amplitude modulation, gain hits, gain steps, or dropouts, cause changes in length of the quiet-tone phasor, with corresponding vertical motion of the CRT spot, as in Figure 1-4B.

b. Tone-correlated phase disturbances such as phase modulation, phase hits, or phase steps, cause rotation of the steady-state tone phasor, with corresponding nearly-horizontal (actually circle arc) motion of the spot, as in Figure 1-4C.

c. Disturbances not correlated with the tone, such as steady noise, impulses, and single frequency interference (SFI), cause motion of the spot in both axes as in Figure 1-4D. Noise causes an unpredictable random motion; impulses cause brief radial excursions at random angles; and SFI causes circular motion as the SFI tone phasor rotates around the tip of the steady-state tone phasor at the difference frequency.

1-20. CLASSIFICATION OF LINE DISTURBANCES (Figure 1-5)

1-21. If a sinusoidal test tone, V_t, is transmitted over a communications channel, the received signal will contain a steady-state tone, the 'quiet tone', plus disturbances and distortion caused by channel transmission impairments.

a. Disturbances that are synchronous with the steady-state received tone are called 'tone-correlated disturbances'; depending on whether they affect the amplitude or phase of the received signal, they are further designated 'tone-correlated amplitude disturbances' or 'tone-correlated phase disturbances'.

b. Disturbances that are not synchronous with the steady-state received tone are called 'non-tone-correlated' or 'uncorrelated' disturbances.

1-22. BASIC EQUATION FOR RECEIVED TEST TONE

1-23. If the transmitted test tone, V_t, is of the form $A_t \cos wt$, where $w = 2\pi f$, the received signal, V_r, will be of the form represented by equation (1-1):

$$V_r = A_r\{1+g(t)\} \cos \{wt+p(t)\} + n(t) + \Sigma\{H_k \cos(kwt+\Phi_{kw})\}. \qquad (1\text{-}1)$$

The functions g(t) and p(t) are respectively disturbances on the amplitude and phase of the steady-state received tone or quiet tone, $A_r \cos wt$; and the last term, where k assumes integral values of 2 and over, is the total harmonic distortion. The function n(t) represents disturbances not correlated with the quiet tone. Note that the reference in this discussion is the quiet tone, $A_r \cos wt$. Equation (1-1) takes no account of the steady-state channel gain, phase shift, or frequency shift. It does consider the difference in phase shift between the tone and its harmonics, Φ_{kw}.

1-24. TONE-CORRELATED AMPLITUDE DISTURBANCES (Figures 1-5A and B)

1-25. The correlated disturbances which affect tone amplitude are amplitude modulation, amplitude or gain hits, amplitude or gain steps, and dropouts.

a. The function g(t) is that function of time which describes the amplitude variation of the received test tone. It has a relatively steady-state component with a zero time average over the measurement bandwidth of the test instrument. This 'amplitude jitter' is the sum of the effects of incidental amplitude modulation, noise and SFI on the signal amplitude. The function g(t) also has discontinuous components with non-zero short-time averages. These components are called amplitude or gain hits, amplitude or gain steps, and dropouts.

b. An amplitude or gain step is a positive or negative step in g(t). It is measured with respect to the recent average level of the test tone, subject to certain rise time and amplitude criteria.

c. An amplitude or gain hit is bidirectional, i.e., a step to a new value and then a return to approximately the original value. It is also measured with respect to the recent average level of the test tone, subject to certain rise time and amplitude criteria.

d. A dropout is a large decrease in level or short-term loss of signal measured with respect to the received tone level at the time a test is started or other appropriate reference level. The recently promulgated definition of a dropout is "a reduction in the received tone voltage level by more than 12 dB with respect to its value at the start of the test, which level stays below this threshold for 10 milliseconds or more." Note the difference between a dropout and a negative gain hit. The latter is defined with respect to a recent average level of the received tone, subject to certain rise-time and amplitude criteria; there is no rise-time criterion for a dropout, merely a level theshold and a minimum duration.

1-26. In the PB-1 suppressed-tone phasor display, amplitude jitter appears as a vertical line, as shown in Figure 1-5A. Its length is a measure of the magnitude of the jitter. Gain Hits appear as transient vertical excursions that return to approximately the initial levels and Gain Steps appear as transient vertical excursions to new levels. Figure 1-5B thus represents a Gain Hit or a Gain Step, depending on how it is read. The AGC tracking loop of the PB-1 suppresses transient excursions in the long term, but it does not do so instantaneously, otherwise both jitter and hits would be masked. Rather it tracks transients with a time constant of nominally 50 milliseconds, so that recovery from a single transient is relatively complete within 1/7 second.

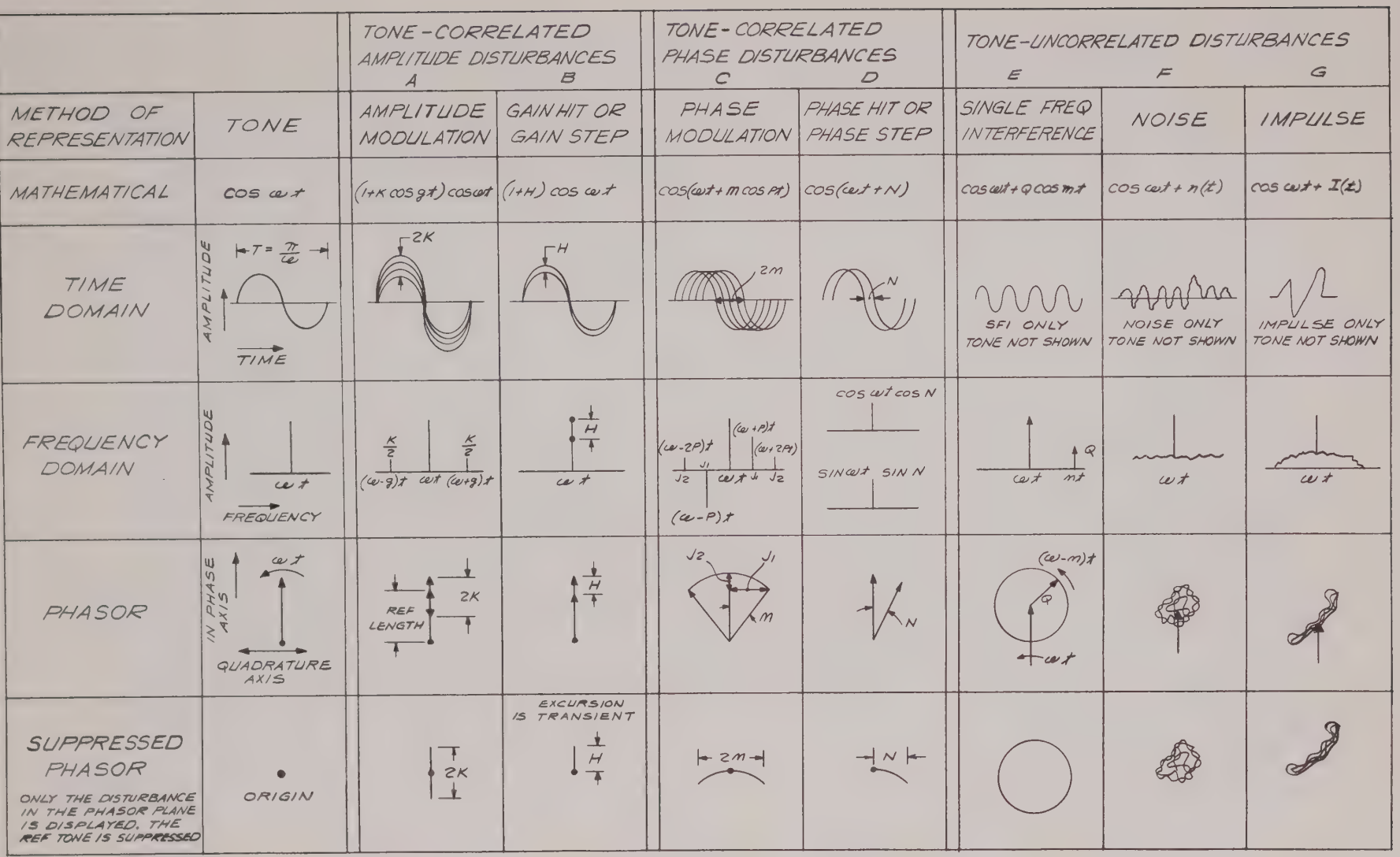

Figure 1-5 Representations of Types of Disturbances

1-27. TONE-CORRELATED PHASE DISTURBANCES (Figures 1-5C and D)

1-28. The function p(t) is that function of time which describes the short-term phase variation. It has a relatively steady-state component with a zero time-average over the instrumentation bandwidth (typically 20-300 Hz). This 'phase jitter' is the sum of the effects of incidental phase modulation and of noise and SFI on the phase of the received test tone. Note in Figure 1-5C that the first sidebands of the jittered tone have an opposite sense as compared to the sidebands of an amplitude modulated tone, and that the second sidebands are AM-like sidebands. This can best be understood by considering the phasor representation. The phasor is rotated plus and minus with respect to reference. This produces a quadrature component between the reference tone and the received tone of amplitude sin θ. It produces an amplitude variation of (1-cos Φ). The amplitude variation occurs at a double frequency; that is, as the phasor rotates from zero positively and back to zero, the amplitude goes through a complete cycle. And likewise, as the phasor rotates from zero negatively back to zero, the amplitude goes through a complete cycle. The complete mathematical expansion for a single frequency of phase jitter involves a series of Bessel functions, of which the first sidebands correspond to J1 and the second sidebands correspond to J2. For normally-encountered jitter, the first two sidebands provide a sufficiently accurate description because of the low index of the modulation.

1-29. Figure 1-5D represents 'before' and 'after' snapshots. It is necessary in the frequency domain representation to consider separately the sin wt and cos wt components of the frequency spectrum. Before the phase hit, the signal energy resides in the cos wt spectrum, and the sin wt spectrum is zero. The hit amounts to transfer of energy from the cosine to the sine spectrum. Note that for a true phase hit, the rms sum of the sine and cosine spectrums remains constant. There is no reference phase in a communication channel; thus there is no phase equivalent to a dropout. The test instrument tracks the phase of the received tone more or less slowly, and a phase hit is defined as an abrupt change with respect to the recent average phase of the received tone. Again, criteria are needed to define both the rate of change and the amplitude of the hit. Both phase steps (unidirectional abrupt changes in phase) and phase hits (transient phase changes which are followed by return to the original phase) are found on typical common carrier facilities.

1-30. In suppressed phasor representation, phase jitter appears as a circle arc or as a horizontal line depending upon its frequency. If the display filter passes the second sideband, the result will be a circle arc; if the jitter frequency is high enough so that the second sideband is outside the filter passband, the display will be a horizontal line. Hits produce transient excursions which are essentially circle chords aimed at the hit angle. The transients are eventually suppressed by the phase lock loop which, as the AGC loop, corrects for a single transient in nominally 1/7 second.

1-31. NONSYNCHRONOUS OR TONE-UNCORRELATED DISTURBANCES (Figure 1-5E,F,G)

1-32. Nonsynchronous disturbances are single-frequency interference (SFI), steady noise, and impulse noise. Figure 1-5E shows a single frequency interfering tone which, when added to the test tone, produces a frequency domain signal as shown. These is a unit-length vector directly upward representing cos wt, plus the additive SFI vector spinning around the tip of the unit vector. The amplitude of this spinning vector is the amplitude of the signal frequency interfering tone relative to the tone amplitude, and the circular frequency of its rotation is the difference frequency between the test tone cos wt and the signal frequency interfering tone. It is, in effect, single-sideband modulation.

1-33. As shown in Figure 1-5F, steady noise is similar to single-frequency interference except that it comprises a spectral distribution of varying amplitude interfering signals. As also depicted in the suppressed phasor representation of Figure 1-5C, there is no single, unique spinning additive vector. The instantaneous value of the output can be any place within the relatively jagged circle. The amplitude of the 'circle' is a measure of the summation of the noise factors as they reinforce and interfere with each other.

1-34. Figure 1-5G shows an impulse. Impulses are highly variable and usually brief, lasting only a few milliseconds. A typical signal-to-steady noise objective of common carriers is 24 dB, whereas the comparable signal-to-impulse noise objective is 5 dB. The difference is acceptable partly because of the short duration of impulse noise, and partly because hit ratios are based on rms/peak, whereas steady ratios are rms/rms. Figure 1-5G represents the instantaneous situation during the impulse which will typically have its energy in some band that is not necessarily symmetric about the tone, and which will not necessarily define a circle in the phasor diagram.

1-35. MEASUREMENT CAPABILITIES OF THE PB-1

1-36. PARAMETERS MEASURED BY THE PB-1

1-37. The PB-1 operates over ranges of ±8% about test tone frequencies of 404, 804, 1004, 1704, and 2804 Hz, and about an optional fixed sixth frequency between 300 and 3000 Hz. At each operating frequency, the PB-1 identifies and measures each of the quantities listed in Pars. 1-38 through 1-43, and provides the audio outputs listed in Par. 1-44.

1-38. Tone Parameters

a. Level

b. Frequency

c. Frequency Hits: bidirectional transient changes in frequency followed by return to the original frequency.

d. Frequency Shift

1-39. Tone-Correlated Amplitude Disturbances

a. Amplitude Jitter: the combined effects of pure amplitude modulation and uncorrelated disturbances (such as noise or SFI) on the amplitude of the received tone.

b. Amplitude Modulation

c. Gain Hits: bidirectional transient changes in amplitude that return to approximately the original amplitude. A positive gain hit is an increase in amplitude followed by a decrease to the original amplitude; a negative gain hit is a decrease in amplitude followed by an increase to the original amplitude. Typical hit durations are 50 to 150 milliseconds.

d. Gain Steps: unidirectional positive or negative transient changes in amplitude.

e. Dropouts: negative gain hits of at least 12 dB for at least 10 milliseconds.

1-40. Tone-Correlated Phase Disturbances

a. Phase Jitter: the combined effects of pure angle (phase or frequency) modulation and uncorrelated disturbances (such as noise or SFI) on the phase of the received tone.

b. Phase Modulation

c. Phase Hits: bidirectional transient changes in phase that return to approximately the original phase.

d. Phase Steps: unidirectional positive or negative transient changes in phase.

1-41. Non-Correlated Disturbances

a. Notched Noise: received signal with quiet-tone removed.

b. Single-Frequency Interference: undesired or spurious steady tones. This category does not include phenomena such as tone bursts that may result from crosstalk of multifrequency signaling on other channels.

c. Impulses

1-42. Distortion

a. 2nd Harmonic Distortion

b. 3rd Harmonic Distortion

c. Phase Intercept Distortion

1-43. PCM Disturbances

a. Quantizing Disturbances

b. Foldback Products

c. Compandor Mistracking

1-44. Audio Outputs

a. In the INPUT position of the SPEAKER switch, the PB-1 input is fed to the loudspeaker.

b. In the NOTCH position of the SPEAKER switch, the Notched Noise, or received signal with quiet-tone suppressed, is fed to the loudspeaker.

1-45. ADDITIONAL DIAGNOSTIC CAPABILITIES OF THE PB-1

1-46. The PB-1 is also capable of detecting and identifying the following 'data-disturbing faults' which have been observed on transmission channels that meet all 'normally measured' performance criteria.

a. Differentiates between jitter, noise, and single-frequency interfering tone (SFI).

b. Differentiates between amplitude jitter and phase jitter. Amplitude jitter is similar to phase jitter except that it is predominantly on the in-phase axis. (Most 9600-bit modems appear to be more sensitive to amplitude jitter than they are to the equivalent sideband energy when it appears as phase jitter.)

c. Measures low-frequency jitter, down to 1 Hz.

d. Measures high-frequency jitter.

e. Detects phase hits and gain hits which are too short or too slow to be registered on conventional hit counters. Continuous small phase hits or gain hits occasionally add linearly with the noise and jitter to place a transient outside the no-go error limit.

f. Indicates hit duration and hit direction.

g. Detects noisy dropouts and fast dropouts.

h. Monitors phase-intercept distortion (PID). Continuous variation of PID corresponds to frequency translation. Rapid variation of PID causes data errors. Brief periods of rapid variation in phase intercept distortion result in phase hits too slow to be seen by conventional hit counters, but in instantaneous frequency shifts large enough to confuse modems.

i. Identifies the location of harmonic distortion sources with respect to (i.e., before or after) any frequency translation which may exist on the channel.

j. Provides facility 'signature' information.

k. The Notched Noise audio output is an important part of the diagnostic capability of the PB-1. It permits audible and visual correlation of disturbances. It is particularly useful for transient phenomena because correlated disturbances (phase and gain hits) and uncorrelated disturbances (impulse hits) have different acoustic signatures.

1-47. APPLICATIONS OF THE MODEL PB-1 VF LINE ANALYZER

1-48. GO/NO-GO EVALUATION OF LINE-MODEM COMPATIBILITY (Figure 1-6)

a. High-speed digital data is transmitted over voice-frequency channels by synchronous modems employing phase and/or amplitude modulation of audio-frequency carriers or 'clocks'. The receiving modem 'recovers' the clock frequency from the transmitted signal; i.e., synchronizes to that clock frequency. Relatively small line impairments can cause errors in such modems; large line impairments can cause loss of synchronization.

b. A synchronous modem transmits N bits of binary data per cycle of a clock frequency by sending one of N encoded states of phase and/or amplitude modulation of that clock frequency, and changing the state once each clock cycle. For example, 16 possible states of the clock frequency may be represented by 16 phasors, as shown in Figure 1-6A. This type of coding is called QAM, denoting an encoding scheme combining both Quadrature and Amplitude Modulation. The entire area of Figure 1-6A represents the modem 'decision space'; the 'constellation' or 'eye' pattern of 'decision points' represents the locations of the tips of the 16 phasors.

c. Line disturbances occurring at any instant during transmission of any phase-and-amplitude-modulated signal will add vectorially to that signal, shifting the tip of the phasor being transmitted at that instant, so the receiving modem will not see the 16 stationary points of the constellation pattern, but will see smeared areas around the theoretical points. The receiving modem can operate without error only if adjacent smeared areas do not overlap. As shown in Figure 1-6B, it is possible to define a geometric figure bounding the maximum permissible areas within which errors will not occur. Disturbances causing overlapping smears, as in Figure 1-6C, will cause errors. Note that each permissible area must frequently include an allowance for harmonic distortion which is measured separately, as explained below, and an allowance for the phasor tip smear resulting from static line impairments such as gain and envelope delay distortion.

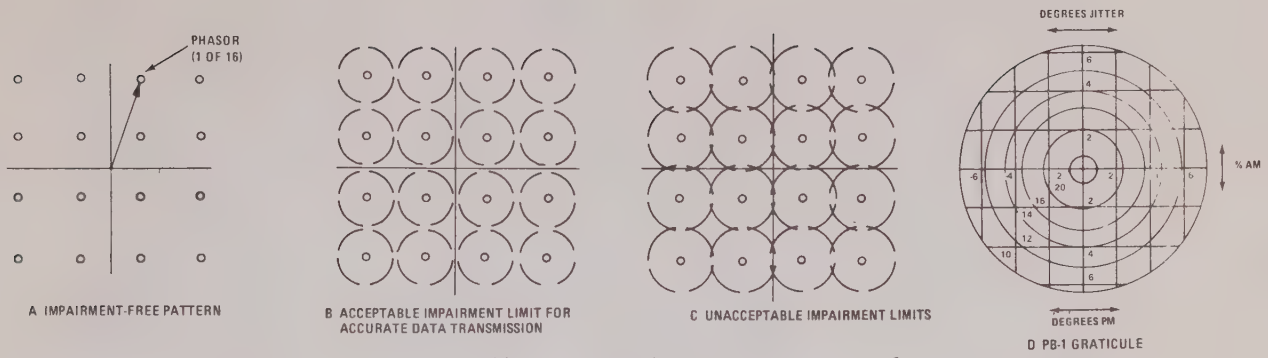

Figure 1-6 Permissible Disturbance Area Around Decision Points in a QAM Modem

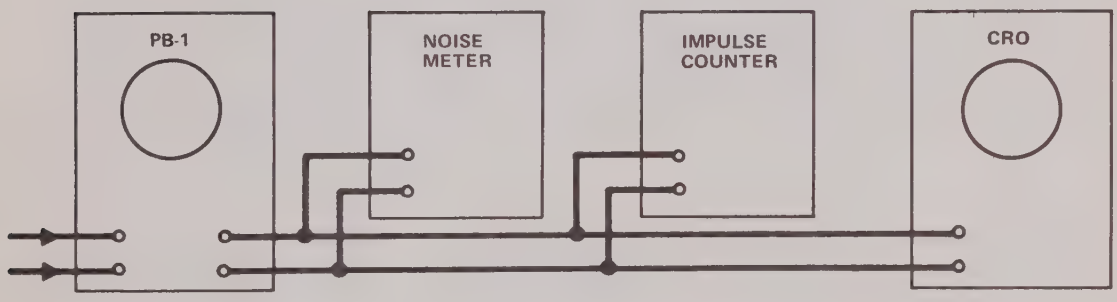

Figure 1-7 PB-1 as a Tracking Notch Filter

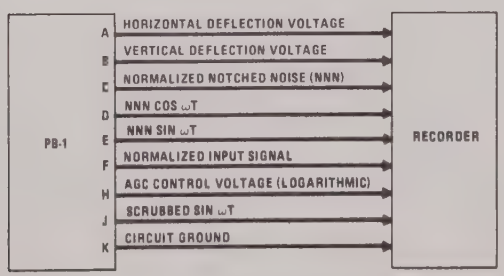

Figure 1-8 Unattended Monitoring of Line Impairments

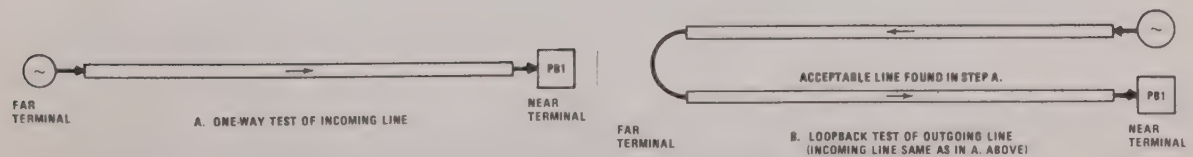
FAR TERMINAL
PB1
NEAR TERMINAL
A. ONE-WAY TEST OF INCOMING LINE
ACCEPTABLE LINE FOUND IN STEP A.
FAR TERMINAL
B. LOOPBACK TEST OF OUTGOING LINE (INCOMING LINE SAME AS IN A. ABOVE)
NEAR TERMINAL

Figure 1-9 Evaluating Dual Dial Backup Lines

d. When a test tone is transmitted over a voice-frequency channel, line disturbances will add vectorially to the tip of the received tone phasor and smear that tip over an area, in exactly the same way as they would smear the tips of the 16 QAM phasors over 16 areas in the modem decision space. If the received tone is examined by a PB-1 VF Line Analyzer, the steady-state tone is suppressed so that (in the VECTOR NOTCH mode) the disturbances can be displayed on an expanded basis, as shown in Figure 1-6D. This is equivalent to continuous high-resolution examination of a single modem decision point. It can immediately be determined whether the line disturbances remain within the permissible area (GO condition) or extend beyond the permissible area (NO-GO condition). Note that the PB-1 views all the instantaneous components of peak noise, thereby identifying not only disturbances which have been classified and are now measured by conventional test equipment, but also disturbances that have not yet been classified, and which are now ignored, even though they affect modem performance.

e. Because the frequency content of a modem signal may extend beyond one octave, and because harmonic distortion modifies the decision space, the line-evaluation procedure should include measurements of 2nd and 3rd harmonics. The PB-1, by measuring (in the VECTOR NOTCH mode) the in-phase and quadrature components of disturbances, and (in the 2ND H and 3RD H modes) the harmonic distortion, defines line performance with respect to modem requirements.

f. Appendix B of this manual describes a procedure for establishing the GO and NO-GO criteria for evaluation of line-modem compatibility.

1-49. TRACKING NOTCH-FILTER FOR OTHER INSTRUMENTS (Figure 1-7)

a. Since the PB-1 tracks and suppresses the steady-state component of received tone, leaving only the disturbances on that tone as 'notched noise' to be analyzed and displayed, it acts as an extremely narrowband notch filter that can track any one of six input tones (404, 804, 1004, 1704, 2804, and f6 Hz) over a ±8% frequency range. The notched noise is available as an electrical output (at front-panel OUTPUT jacks and at a nine-pin rear connector) for use by other instruments, as shown in Figure 1-7.

b. When fed to conventional noise meters, the notched-noise output causes those meters to operate as notched noise meters.

c. The same notched-noise output permits impulse counters to operate on lines in the presence of holding tones without being triggered by those tones.

d. The notched noise can also be fed to the vertical input of a cathode-ray oscilloscope for display in the time domain.

1-50. UNATTENDED MONITORING OF LINE IMPAIRMENTS (Figure 1-8)

a. A number of other useful voltages derived by the PB-1 from the input signal are available at the nine-pin connector on the rear of the instrument. When fed to a multi-channel strip-chart recorder or tape recorder, as shown in Figure 1-8, these outputs permit unattended monitoring of line impairments. The recorded data may be analyzed at leisure, and used to prove the existence of various line impairments.

1-51. EVALUATING DUAL DIAL BACKUP LINES (Figure 1-9)

a. The PB-1 can simplify and expedite the procedure of establishing a two-way Dial Network backup for private or leased lines between a near terminal and a marginally-attended or unattended far terminal, by reducing the problem from that of simultaneously finding two acceptable lines at each dialing to that of finding one acceptable line at each dialing.

b. When either or both of a pair of private or leased lines fails to transmit data satisfactorily between a near or local terminal and a far or remote terminal, it is common to use the Dial Network as a backup, by dialing two lines between the terminals for full duplex operation. To be certain that the two backup lines are useable in the intended directions, they must be checked out in those directions. Assuming that the means of verifying good lines is at the near terminal, the lines are looped back at the far terminal, and digital data (in the case of digital loopback) or a test tone (in the case of analog loopback) are sent around the loop from and to the near terminal. If the loop-around signal is not satisfactory, two new lines are dialed and the test is repeated, until a satisfactory loop is obtained. Note that two lines must be rejected if the loop is not acceptable, even though one of the lines may be good. This necessitates dialing and testing until two simultaneously acceptable lines are found.

c. The PB-1 permits one satisfactory line be found at each attempt, as follows. The far-end transmit line is dialed and the far end sends a tone along this line to a PB-1 at the near end (Figure 1-9A). If the PB-1 indicates that the line is not satisfactory, alternate lines are dialed and tested until the PB-1 indicates that the line is satisfactory. That line is held, and the far-end receive line is dialed. This line is looped to the far-end transmit line, and the near end sends a tone through the loopback to the PB-1 (Figure 1-9B). Since the far-end transmit line is known to be good, only far-end receive lines need be dialed, until the PB-1 indicates that the loopback is good. The loopback test can alternatively be performed on a digital basis, once the return path has been established as acceptable by the remote oscillator and local PB-1.

1-52. CHECKING QUALITY OF TEST-TONE SOURCES

a. It is advisable to use the PB-1 to check station test-tone sources initially and periodically. This is done by patching the PB-1 directly to the tone source and observing the source output with maximum sensitivity in the VECTOR NOTCH, 2ND H, and 3RD H modes.

b. This procedure assures that when a test-tone source is used for testing transmission channels, there are no disturbances (i.e., harmonics, level and/or frequency shifts, phase and/or amplitude modualtion, hum, noise, etc.) on the test tone that would be erroneously attributed to the transmission channels under test.

1-53. IDENTIFICATION OF FACILITIES BY VISUAL/ACOUSTIC SIGNATURES

a. The time constants of the AGC loop and of the Phase-Lock Loop are such that both loops operate rapidly enough to recover from transients within the 1/7 second dead-zone interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients. The PB-1 therefore responds to transients in ways that identify them acoustically. Gain or phase hits 'pull' the tracking loops, thus momentarily degrading the notch, and causing a 'ping' as the tone 'leaks' through during the recovery period. Low-frequency steady-state modulation also pulls the loops, causing a 'wow'. Impulse hits do not pull either tracking loop; they cause a 'pop'.

b. The PB-1 visual and acoustic outputs frequently permit identification of telephone transmission facilities through which the test tone may pass. FDM, PCM, and Copper facilities have characteristic impairment patterns which frequently permit identification.

BRADLEY TELCOM V-F LINE ANALYZER MODEL PB-1

THE MODEL PB-1 VOICE-FREQUENCY LINE ANALYZER IS A COMPACT, LIGHTWEIGHT, PORTABLE INSTRUMENT WHICH:

- **Detects All Disturbances,** Including Types Ignored By Other Instruments
- **Provides Comprehensive Diagnostic Capability**
- **Makes Go/No-Go Evaluation of Lines,** Using Voice or Data Criteria

FEATURES OF THE PB-1 VF LINE ANALYZER:

Operates At Five Selectable Tone Frequencies: Three standard Bell System and CCITT frequencies **(400, 1,000,** and **2,800 Hz)** for gain slope and envelope delay slope measurements; European **(800 Hz)** and American **(1,000 Hz)** dialable tone frequencies, for results compatible with Jitter Sets, Hit Counters, etc.; **1,700** Hz with ± (20 – 600) Hz bandpass for 'frequency window' that brackets dotting pattern of several FSK modems. Optional sixth frequency, factory-installed and set to any specified frequency in 300 to 3,000 Hz range. Tracks each operating frequency over ± 8% range.

Analyzes Complex Phenomena: Separates, Classifies, and Identifies each type of Disturbance, and Measures Magnitude, Sense or Direction, and Duration. Distinguishes among Noise, Jitter, and Single-Frequency Interference. Distinguishes among Impulse Hits, Phase Hits, and Gain Hits. Detects Phase and Amplitude Jitter outside the bandpass of other instruments.

Identifies and Measures Test-Tone Parameters: Level, Frequency, Frequency Shift, Frequency Hits.

Identifies and Measures Tone-Correlated Amplitude Disturbances: Amplitude Jitter, Amplitude Modulation, Gain Hits, Gain Steps, Dropouts, Fast Dropouts, Noisy Dropouts; detects Gain Hits too short or too slow to be detected by conventional Hit Counters.

Identifies and Measures Tone-Correlated Phase Disturbances: Phase Jitter, Phase Modulation, Phase Hits, Phase Steps; detects Phase Hits too short or too slow to be detected by conventional Hit Counters.

Identifies and Measures Non-Correlated Disturbances: Notched Noise, Impulse Noise, Single-Frequency Interference.

Identifies and Measures Distortion: Second Harmonic Distortion, Third Harmonic Distortion, Time-Varying Phase-Intercept Distortion. (Rapidly-varying phase-intercept distortion causes data errors).

Identifies PCM Disturbances: Quantizing Disturbances, Foldback Products, Compandor Mistracking, Timing Breakup.

Provides Visual and Acoustic Outputs For Operator, and Electrical Outputs For Auxiliary Instruments and Recorders

Identifies Transmission Facilities By 'Signature': L, N, and T carrier, and copper pair, have characteristic visual and acoustic outputs.

Provides Automatic-Tracking Notch Filter Output that converts conventional Noise Meters into Notched Noise Meters, and that permits conventional Impulse Counters to be used in presence of holding tones.

Makes Go/No-Go Determination of Lines For Compatibility With Modems: Permits quantitative inspection of total in-phase and quadrature uncertainties caused by transmission channel impairments.

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TESTING OF VOICE AND DATA TRANSMISSION FACILITIES

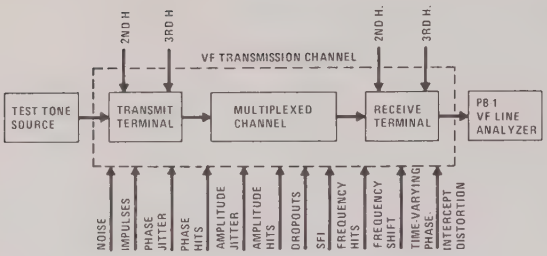

Figure 2-1 One-Way Facility Testing

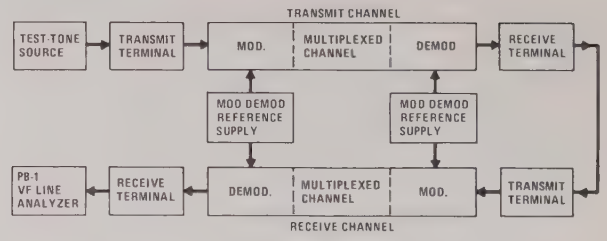

Figure 2-2 Loopback Facility Testing

The telephone network was designed primarily to route and transmit voice communications. The performance characteristics of the voice-frequency channels of the telephone network are therefore not optimized for transmission of digital data. As a result, problems frequently arise in the transmission of data over the telephone network, and those problems increase greatly with the rate of data transmission. Moreover, certain types of equipment, such as compandors and echo suppressors, that are provided in the telephone network to improve voice communications, may even cause problems when that network is used for data transmission.

When subscribers use data sets or 'modems' supplied by common carriers, to transmit and receive data over common carrier telephone facilities, the major responsibility for solving any data transmission problems is obviously that of the carriers. However, when subscribers use modems **not** supplied by common carriers, to transmit data over common carrier telephone facilities, the responsibilities for data transmission problems may not be so clear. Such problems may arise because of deficiencies in the modems, in the facilities, or in both. It then becomes necessary for both subscribers and common carriers to be able to test the telephone network facilities, in order to determine the sources of problems. Such testing must be made not only against voice transmission criteria, but also against data transmission criteria.

Telephone network transmission channels perform differently when loaded and when idle. Since only channels loaded with data can induce disturbances on that data, they are preferably tested in the loaded condition. One method of loading a channel for testing is to transmit a 'holding' tone through that channel. The Model PB-1 VF Line Analyzer utilizes such tones as test tones, and monitors the received tones (i.e., after transmission through channels under test) for disturbances induced on those tones by channel impairments. Figure 2-1 shows the basic configuration for one-way testing of a telephone transmission facility, and Figure 2-2 shows the configuration for loopback testing. Various types of disturbances that can be induced on a test tone are shown in Figure 2-1. Harmonic distortion is introduced only at the terminals, because harmonics occurring after the channel has been multiplexed will fall out of band. Although not shown in Figure 2-2, the disturbances shown in Figure 2-1 can be introduced into both the transmit and receive channels of a loopback connection. One-way testing detects disturbances in one direction, and loopback testing detects the sum of the disturbances in both directions. In loopback testing, some disturbances may be introduced equally and oppositely in each direction, and thus cancel out, e.g., REFERENCE SUPPLY problems. Thus, though loopback testing may be more convenient, the results of such testing should be confirmed if possible, by one-way testing in at least one of the two directions, to ascertain that there are no significant one-way impairments that have been canceled out by looping back.

SUPPRESSED-TONE PHASOR-DOMAIN MEASUREMENTS

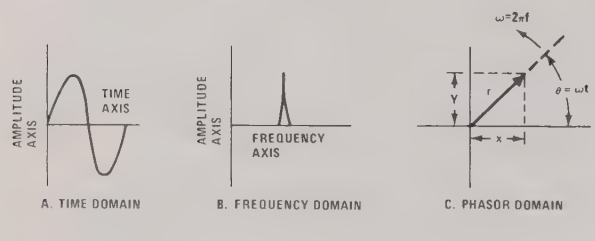

Figure 2-3 Representations of a Sinusoidal Tone In Three Domains

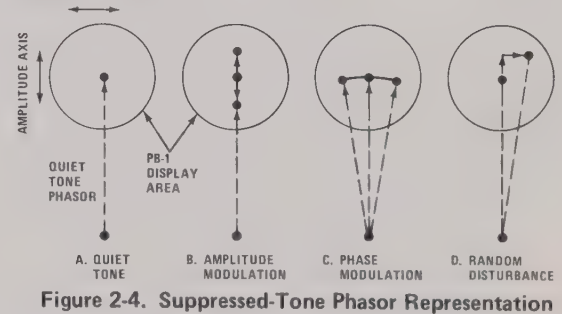

Figure 2-4. Suppressed-Tone Phasor Representation

Suppressed-tone phasor-domain representation is a new technique for rapid display, classification, identification, and measurement of all disturbances induced on a test tone by a transmission channel.

Signals are conventionally represented in the time domain (Figure 2-3A), as displayed by oscilloscopes, and in the frequency domain (Figure 2-3B), as displayed by spectrum analyzers. Signals may also be represented in the phasor domain, and displayed on suitable instruments, such as the PB-1 VF Line Analyzer.

In the phasor domain, a sinusoid of frequency f(Hz) is represented by a radius vector called a phasor, which hypothetically rotates about its origin at the angular velocity $\omega(=2\pi f)$ radians per second (Figure 2-3C), but which appears stationary because it is illuminated at exactly the same position in each rotation by a hypothetical stroboscope. The amplitude of the sinusoid is represented by the length of the phasor, and the phase of the sinusoid is represented by the angular position of the phasor at the instant of 'illumination'. One common 0° angle reference for phasors is the horizontal to the right of the origin (Figure 2-3C); another, used by the PB-1, is the vertical up from the origin (Figure 2-4A). Note that phasors may be represented either by the polar coordinates r(length) and θ(angle with respect to the 0° reference), or by the rectangular coordinates which represent the projections or 'shadows' of the phasor on the in-phase axis and on the quadrature axis respectively. These shadows describe the familiar time-domain sine wave. As the phasor rotates through 360°, the sine (or cosine) wave goes through a complete cycle.

When a pure sinusoidal test tone is transmitted through a voice-frequency communication channel, impairments in the channel may induce on that tone a wide range of disturbances such as noise, phase modulation, amplitude modulation, interfering tones, harmonics resulting from nonlinear distortion, and transients of various kinds. If the steady-state component of the received signal (i.e., the 'quiet tone') is displayed as a vertical phasor (Figure 2-4A), the disturbances (which are not stationary with respect to the tone) will add (vectorially, and on

an instantaneous basis) to the tip of that phasor. The entire phasor need not be shown, because its coordinates, whether polar or rectangular, are completely defined by a point representing the location of its tip with respect to the reference axes. Since disturbances are usually much smaller in amplitude than the test tone, the tip of the resultant phasor (representing the vector sum of the steady-state received tone plus instantaneous disturbances) is normally confined to a small area around the tip of the steady-state tone phasor. This is the area that is displayed by the PB-1 in its VECTOR NOTCH mode. By suppressing the steady-state tone phasor (which contains no information about disturbances) so that the tip of that phasor is at the center of the display, the PB-1 shows only the disturbance phasors. These can therefore be shown on a greatly enlarged scale, thus increasing the resolution and accuracy with which those disturbances can be measured.

The direction and amplitude of the disturbance phasors on the suppressed-tone phasor display depend on the nature and amplitude of the disturbances. Tone-correlated amplitude disturbances such as amplitude modulation, gain hits, gain steps, or dropouts, cause changes in length of the steady-state tone phasor, with corresponding vertical motion of the CRT spot (Figure 2-4B). Tone-correlated phase disturbances such as phase modulation, phase hits, or phase steps, cause rotation of the steady-state tone phasor, with corresponding nearly-horizontal (actually circle arc) motion of the spot (Figure 2-4C). Disturbances not correlated with the tone, such as steady noise, impulses, and single frequency interference (SFI), cause motion of the spot in both axes (Figure 2-4D). Noise causes an unpredictable random motion; impulses cause radial excursions at random angles; and SFI causes circular motion as the SFI tone phasor rotates around the tip of the steady-state tone phasor at the difference frequency.

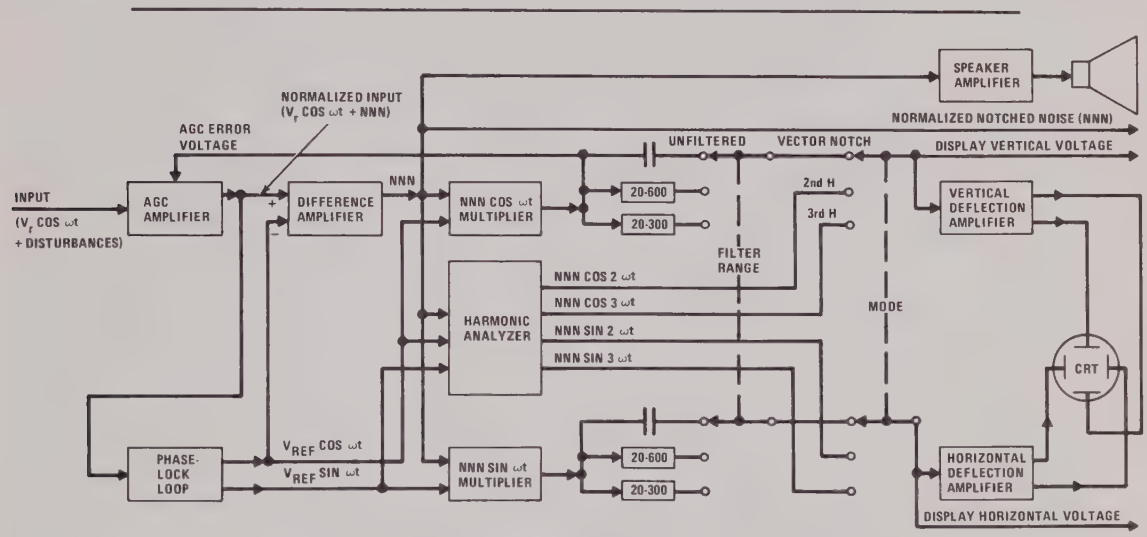

Figure 3-1 PB-1 VF Line Analyzer, Simplified Block Diagram

THEORY OF OPERATION OF MODEL PB-1 VF LINE ANALYZER*

The PB-1 employs two high-gain closed loops, an Automatic Gain Control (AGC) loop and a Phase-Lock Loop (PLL), which are interconnected to operate as a narrowband notch filter that automatically tracks and suppresses a steady-state tone. A received signal, comprising a steady-state test tone (V_r cosωt) and accompanying disturbances caused by impairments in the transmission channel under test, is amplified by the AGC Amplifier so that the steady-state tone (V_r cosωt) is normalized by being made equal to a reference voltage (V_{ref} cosωt) from the PLL. The normalized steady-state tone and its disturbances (which remain in scale to that tone) are fed to a Difference Amplifier and to the PLL. The PLL locks on to the tone component (V_r cosωt), and develops two orthogonal reference voltages: V_{ref} cosωt, in phase with the steady-state tone; and V_{ref} sinωt, in quadrature with the steady-state tone. The in-phase reference voltage is fed to the Difference Amplifier and to the NNN Cos ωt Multiplier. The quadrature reference voltage is fed to the NNN Sin ωt Multiplier.

The output of the Difference Amplifier is the normalized input signal with the normalized received tone removed, leaving only the normalized disturbances. Disturbances remaining after a test tone has been removed, suppressed, or 'notched' from a signal, are conventionally called 'notched noise'. Since the PB-1 notches the steady-state tone from the **normalized** signal, the remaining disturbances will be referred to as 'normalized notched noise' (NNN).

The NNN output of the Difference Amplifier is fed to the NNN Cos ωt Multiplier, to the NNN Sin ωt Multiplier, and through an amplifier to a loudspeaker. The NNN Cos ωt Multiplier output is the NNN component in phase with the steady-state tone; this is fed, through the FILTER RANGE and MODE switches, to the CRT Vertical Deflection Amplifier.

The NNN Sin ωt Multiplier output is the NNN quadrature component; this is fed, through the FILTER RANGE and MODE switches, to the CRT Horizontal Deflection Amplifier. Since these components are normalized, the corresponding CRT deflections may be measured against CRT graticule scales calibrated relative to the received test tone. The voltage NNN cos ωt is also used as the error voltage that causes the AGC Amplifier to normalize the received signal so that the received tone equals the in-phase reference tone from the PLL.

The time constants of the AGC and Phase-Lock Loops are selected so that the loops operate rapidly enough to recover from transients within the conventional 1/7 second dead time interval of Hit Counters, but do not operate so rapidly that they mask Hits, Steps, or other transients.

The NNN voltage from the Difference Amplifier and the in-phase and quadrature reference voltages from the PLL are fed to a Harmonic Analyzer that develops in-phase second and third harmonic components, and quadrature second and third harmonic components, of the Normalized Notched Noise. In the 2ND H position of the MODE switch, the in-phase second-harmonic component (NNN cos 2ωt) is fed to the vertical deflection amplifier, and the quadrature second harmonic component (NNN sin 2ωt) is fed to the horizontal deflection amplifier. Similarly, in the 3RD H position of the MODE switch, the in-phase third-harmonic component (NNN cos 3ωt) is fed to the vertical deflection amplifier, and the quadrature third harmonic component (NNN sin 3ωt) is fed to the horizontal deflection amplifier.

The voltages selected for display by the MODE switch are also available as electrical outputs for use in a number of ways that are discussed in the applications pages of this bulletin.

*U.S. Patents 3,814,868, 3,927,281 and 3,906,173; other U.S. and foreign patents pending.

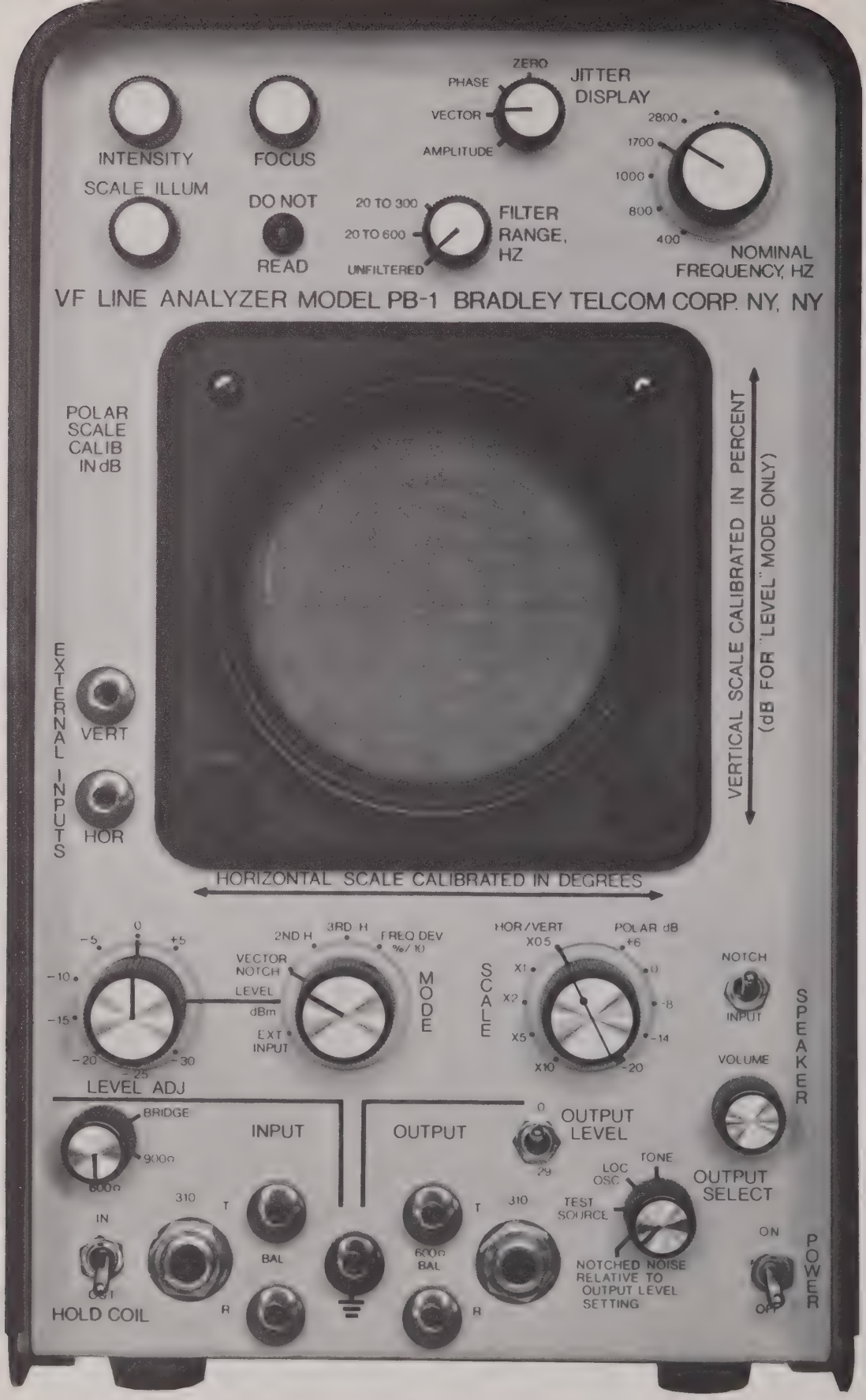

Figure 4-1 PB-1 VF Line Analyzer, Actual Size

PB-1 CONTROLS AND FUNCTIONS

DO NOT READ lamp, in normal off condition, indicates that Phase Lock Loop is locked to signal, and that AGC loop is near the center of its operating range, thus providing equal margins for positive and negative excursions. The LEVEL ADJ switch is set so that the DO NOT READ lamp is normally off, but large transient excursions may cause lamp to go on. PB-1 can still be used, even if DO NOT READ lamp is on, as long as CRT display indicates that Phase-Lock Loop is locked to signal; i.e., behaves normally.

EXTERNAL INPUT (HOR and VERT) banana jacks permit using the PB-1 as an X-Y oscilloscope or vectorscope, when MODE switch is at EXT INPUT, to display modem 'constellation' or 'eye' patterns or decision spaces.

LEVEL ADJust switch offsets the input tone level (in 5 dB steps from −30 dBm to +5 dBm), to permit accurate level measurement in LEVEL, dBm mode. LEVEL ADJ switch settings indicate input levels that result in zero vertical spot deflection on the CRT when the MODE switch is at LEVEL, dBm; other levels will cause vertical deflection of spot. If input signal is more than approximately 4 dB from LEVEL ADJ switch setting, DO NOT READ lamp will light, regardless of MODE switch setting.

INPUT banana jacks that accept standard double banana plugs are multipled with phone jack that accepts WE310/PJ051 phone plugs.

Termination Switch selects balanced 600Ω, 900Ω, or BRIDGING (25,000 ohm) input impedances for input jacks.

HOLD COIL switch and a holding coil compatible with 48 VDC central office batteries, are a factory-installed option. When switch is set to IN, holding coil is connected across input; when switch is set to OUT, holding coil is disconnected from input.

NOMINAL FREQUENCY switch selects operating frequency range over which notch filter will track an input tone. Nominal frequencies and actual operating ranges are:
a. **400:** 404 Hz ± 8% (372 to 436 Hz)
b. **800:** 804 Hz ± 8% (740 to 868 Hz)
c. **1000:** 1004 Hz ± 8% (924 to 1084 Hz)
d. **1700:** 1704 Hz ± 8% (1568 to 1840 Hz)
e. **2800:** 2804 Hz ± 8% (2580 to 3028 Hz)
f. Sixth position for factory-installed optional frequency in 300 to 3000 Hz range. Notch filter will track actual input over ± 8% range about this frequency.

JITTER DISPLAY switch is effective only when MODE switch is at VECTOR NOTCH.

a. **ZERO** position grounds both Horizontal and Vertical Deflection Amplifiers, permitting CRT spot to be set to origin by means of HOR and VERT ZEROING adjustments at rear of instrument.

b. **PHASE** position displays only the quadrature component of Normalized Notched Noise, as a horizontal deflection.

c. **VECTOR** position displays both in-phase component and quadrature component of Normalized Notched Noise, as vertical and horizontal deflections, respectively.

d. **AMPLITUDE** position displays only the in-phase component of Normalized Notched Noise, as a vertical deflection.

FILTER RANGE switch is effective only when MODE switch is at VECTOR NOTCH. This switch simultaneously selects filter bandwidths for both in-phase and quadrature components of Normalized Notched Noise, as follows:

a. **20-600** position: Display contains only Normalized Notched Noise components in sidebands ± (20 Hz to 600 Hz) around test tone frequency.

b. **20-300** position: Display contains only Normalized Notched Noise components in sidebands ± (20 Hz to 300 Hz) around test tone frequency.

c. **UNFILTERED** position: Display contains only Normalized Notched Noise components in band from 20 Hz to 1 Hz below tone frequency, and in band from 1 Hz above tone frequency to 3500 Hz.

MODE Switch selects one of six different display modes, as follows:

a. **EXT INPUT** mode connects HOR and VERT EXTERNAL INPUT jacks to the CRT deflection circuits through the SCALE switch, for display of modem 'constellation' or 'eye' patterns or decision spaces.

b. **LEVEL, dBm** mode permits dBm level of input test tone to be read as the sum of the CRT vertical deflection (multiplied by SCALE factor) and the setting of the LEVEL ADJ switch for which the DO NOT READ lamp is off. If the SCALE switch is set to X1, the CRT vertical deflection is direct-reading in dB. This spot deflection value is added algebraically to the LEVEL ADJ setting to obtain the input tone level in dBm.

c. **VECTOR NOTCH** mode displays Normalized Notched Noise in-phase and quadrature components (NNN Cos ωt and NNN Sin ωt) as vertical and horizontal deflections, respectively, modified by the settings of the JITTER DISPLAY and FILTER RANGE switches.

d. **2ND H** mode displays amplitude and phase of Normalized Notched Noise components within ±3 Hz of the second harmonic frequency, 2f.

e. **3RD H** mode displays amplitude and phase of Normalized Notched Noise components within ± 3 Hz of the third harmonic frequency, 3f.

f. **FREQ DEV %/10** mode displays deviation of test tone frequency from the specified value (i.e., 404, 804, 1004, 1704, 2804 Hz) as a vertical deflection. Calibration is direct-reading in Percent when SCALE switch is at X10.

SCALE switch controls CRT amplifier deflection sensitivities. Diametral line on the knob simultaneously indicates the HOR/VERT scale factor to the left, and the POLAR dB scale factor to the right. These are related to the graticule scales as follows:

Both the horizontal and vertical scales on the CRT graticule are numbered ± (2, 4, 6). The horizontal scale represents angular degrees relative to tone phase; and the vertical scale represents percent of tone level in all modes except the dBm LEVEL mode and the FREQ DEV %/10 mode described above. Although the units represented by the horizontal and vertical scales are different, the numbers are the same, so that the same SCALE multiplication factors apply.

The POLAR dB graticule circles are calibrated in -10, -12, -14, -16, -20, and -30 dB from the outermost to the innermost. The innermost circle is not numbered. Since the circle calibrations represent dB relative to the POLAR dB setting of the SCALE switch, the graticule dB values must be added algebraically to the POLAR dB value of the SCALE switch position. This sum represents dB relative to the test tone, or 'dB separation' from the test tone.

SPEAKER TONE/NOTCH toggle switch selects signal fed to loudspeaker:

a. **TONE** position feeds received tone to loudspeaker.

b. **NOTCH** position feeds Normalized Notched Noise to loudspeaker.

SPEAKER VOLUME control adjusts acoustic output level of speaker.

600Ω BAL OUTPUT banana jacks that accept standard double banana plugs are multipled with phone jack that accepts WE310/PJ051 phone plugs.

OUTPUT LEVEL toggle switch selects either 0 dBm or -29 dBm output level, when OUTPUT jacks are terminated by a 600-ohm load.

OUTPUT SELECT switch selects signal fed to OUTPUT jacks.

a. **TONE** position opens Phase-Lock Loop and converts PB-1 into a test-tone oscillator at 404, 804, 1004, 1704, or 2804 Hz, all ± 0.25%, as selected by the NOMINAL FREQUENCY switch. Note that, in the TONE position of the OUTPUT SELECT switch, only the EXT INPUT position of the MODE switch is operational.

b. **LOC OSC** position: output tracks input frequency, but is 'scrubbed' or noise-free.

c. **TEST SOURCE** position: output tracks input frequency, but contains large harmonic content for use in frequency translation and phase-intercept distortion measurements.

d. **NOTCHED NOISE RELATIVE TO OUTPUT LEVEL SETTING:** output is Normalized Notched Noise.

VECTOR NOTCH MODE LINE ANALYSIS WITH THE PB-1

The diagnostic and measurement capabilities of the PB-1 are illustrated on pages 6 through 9. All of the data on pages 6 and 7 were obtained using a 1004 Hz test tone at -16 dBm (the typical level at subscriber sets), with the PB-1 MODE switch at VECTOR NOTCH, JITTER DISPLAY switch at VECTOR, and SPEAKER switch at NOTCH.

The bandwidth of the VECTOR NOTCH display is determined by the FILTER RANGE switch, which has three positions labeled (20-300 Hz), (20-600 Hz) and UNFILTERED. The left-hand photograph of each pair was taken with the FILTER RANGE switch at (20-300 Hz), and the right-hand photograph of each pair was taken with the FILTER RANGE switch at UNFILTERED. The (20-300 Hz) filter provides VECTOR NOTCH displays (left-hand photos) compatible with conventional Bell System and CCITT Phase Jitter test sets and with the Bradley Telcom Model 75LMA Phase and Amplitude Jitter Set. However, this filter limits the disturbance bandwidths displayed to those in the sidebands 20 to 300 Hz below the test tone and 20 to 300 Hz above the test tone. In contrast, the UNFILTERED VECTOR NOTCH mode provides displays (right-hand photos) showing the entire spectrum of disturbances from 30 to 3500 Hz, with a notch bandwidth so narrow that disturbance frequencies within 1 Hz of the test tone frequency may be observed.

In the detection of modulation impairments, the notched noise is translated downward in frequency by the amount of the test tone and is thus centered at dc with the lower sideband folded back onto the upper sideband. This is accomplished by an internal modulator which multiplies the notched noise by the reference tone. At the same time, the same modulator translates the notched noise up to twice the tone frequency, because the modulator produces the sum as well as the difference frequencies of its two inputs. The dc-centered sidebands produce the 20 to 300 Hz picture. The dc-centered plus the double-tone-frequency sidebands produce the UNFILTERED mode picture. Note that modulation impairments show up two ways in the UNFILTERED mode. This is really a reflection of the instrumentation used to reduce them to a display and not a picture of what is actually happening to the tip of the tone vector. It is useful because it 'flags' or calls attention to the modulation impairments, allowing them to be observed even in the presence of a larger amount of noise. The same thing is true in amplitude jitter where the circles are vertically oriented. For transient modulation impairments, the circles grow or expand to one side or the other depending upon the hit direction and its dynamics. In low frequency modulation phenomena, the circles oscillate back and forth or up and down at the modulation frequency.

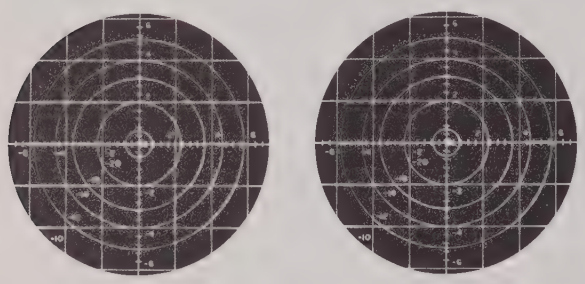

Figure 6-1

QUIET TONE: All disturbances more than 50 dB below tone level.
Display: Spot at origin (tone phasor tip stationary).
Sound: Inaudible

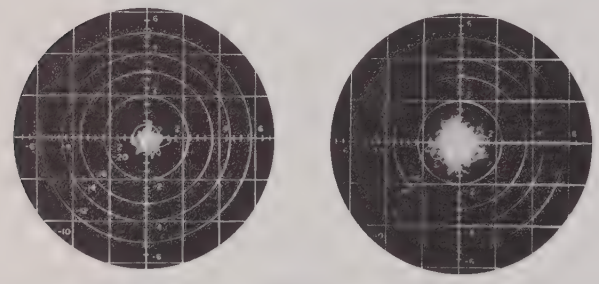

Figure 6-2

STEADY NOISE: White Noise 25 dB below tone level.
Display: Spot moves in random manner around origin. Note that because of wider bandwidth, the UNFILTERED display passes more noise.
Sound: Steady hiss

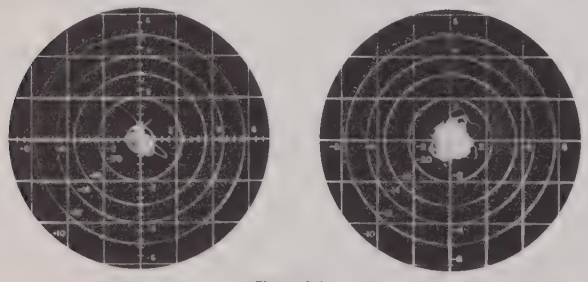

Figure 6-3

STEADY NOISE PLUS IMPULSE: White Noise 25 dB below tone level, plus single impulse 10 dB below tone level. The impulse shown, which has an 800 to 2,300 Hz flat spectrum, is representative of impulses occurring on VF channels.
Display: Transient deflection at random angle. The steady White Noise typically does not 'modulate' or widen the impulse transient deflection because the impulse is too short to 'pull' the AGC or Phase-Lock Loop. See Phase Hit (Figure 7-4) and Gain Hit (Figure 7-7) for contrast.
Sound: Steady hiss with 'pop' at time of impulse.

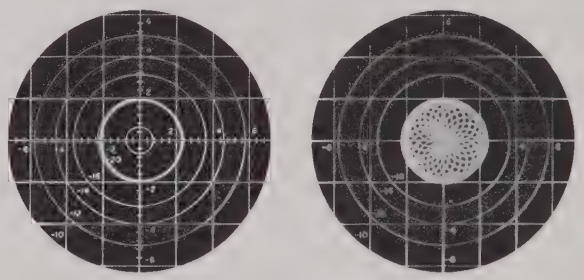

Figure 6-4

SINGLE-FREQUENCY INTERFERENCE (SFI): 10% SFI (i.e., 20 dB below tone level) at 1100 Hz.
Display: Spot traces circle about origin as SFI phasor spins around tip of tone phasor at difference frequency of 100 Hz (=1100 Hz-1000 Hz). The difference frequency is within the passband of the 20 to 300 Hz filter.
Sound: 1100 Hz tone.

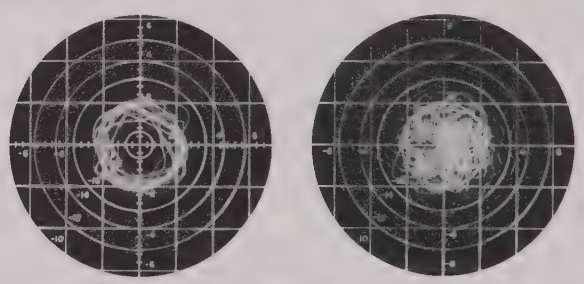

Figure 6-5

SFI PLUS STEADY NOISE: 10% SFI (20 dB below tone level) at 1100 Hz, plus White Noise 25 dB below tone level.
Display: Characteristic doughnut shape as SFI circular trace is widened by noise.
Sound: Steady hiss plus 1100 Hz tone.

Figure 6-6

FREQUENCY HIT PLUS STEADY NOISE: White Noise 25 dB below tone level, plus a single 2-Hz Frequency Hit.
Display: Spot deflects and then spirals back toward origin as the Phase Lock Loop acquires and tracks the new frequency. Trace is modulated by the noise.
Sound: Steady hiss with loud tone-frequency 'ping' at time of hit.

Figures 7-1 through 7-4 below show various types of tone-correlated phase disturbances

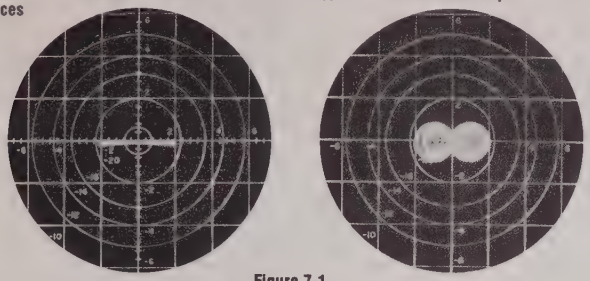

Figure 7-1

PHASE MODULATION: 10° Phase Modulation at 100 Hz.
Display: Spot traces a nearly horizontal circular arc. Note that the UNFILTERED display passes upper PM sidebands. See comments on Filtered and Unfiltered Displays on Page 6. The diameter of the circles is PM magnitude.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone).

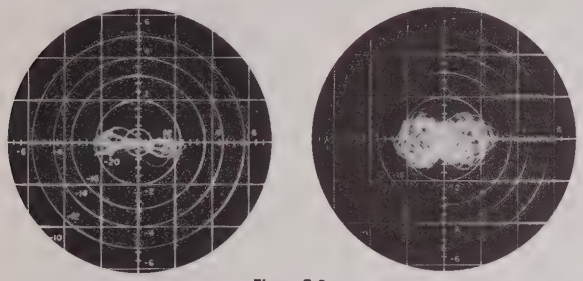

Figure 7-2

PHASE MODULATION PLUS STEADY NOISE: 10° Phase Modulation at 100 Hz plus White Noise 25 dB below tone level.
Display: Horizontal dispersion exceeds vertical dispersion.
Sound: Steady hiss plus 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz).

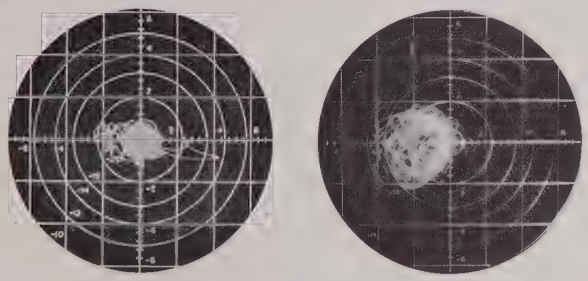

Figure 7-3

PHASE STEP PLUS STEADY NOISE: 10° Phase Step with 4 millisecond rise time, plus White Noise 25 dB below tone level.
Display: Phase transient causes essentially horizontal deflection of spot. Phase Lock Loop moves to the new phase with a recovery time of 1/7 second. During this recovery time, any noise present on the signal vertically modulates or widens the essentially horizontal transient excursions. The UNFILTERED display shows momentary appearance of a sideways-oriented circle for the duration of hit and the recovery time of the instrument. Its diameter is the hit magnitude.
Sound: Steady hiss with tone-frequency 'ping' at time of hit.

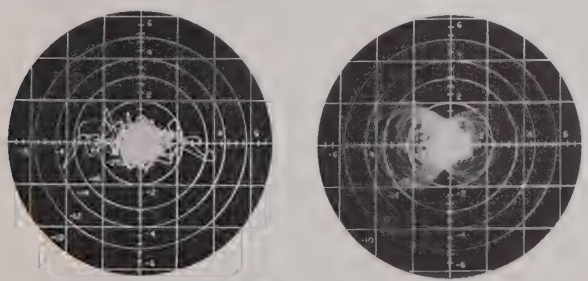

Figure 7-4

PHASE HIT PLUS STEADY-NOISE: 20° Phase Hit with 4 millisecond rise time and 100 millisecond duration, plus White Noise 25 dB below tone level.
Display: Same as Figure 7-3, except that horizontal excursion is symmetrical about origin. The UNFILTERED display circle alternately appears to the left and right at a rate dependent upon the hit duration and rise time.
Sound: Steady hiss with tone-frequency double 'ping', one at leading edge and one at trailing edge of hit. This double ping can be audibly resolved for Phase Hit durations as short as 40 milliseconds.

Figures 7-5 through 7-8 below show various types of tone-correlated amplitude disturbances

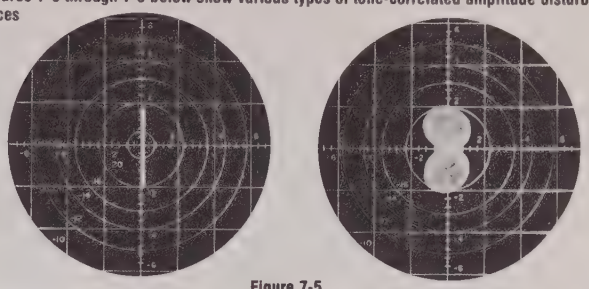

Figure 7-5

AMPLITUDE MODULATION: 10% AM at 100 Hz.
Display: Spot makes vertical trace symmetrical about origin. The UNFILTERED display passes the upper AM sidebands; see comments on Filtered and Unfiltered Displays on Page 6. The diameter of the circle is the AM.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone).

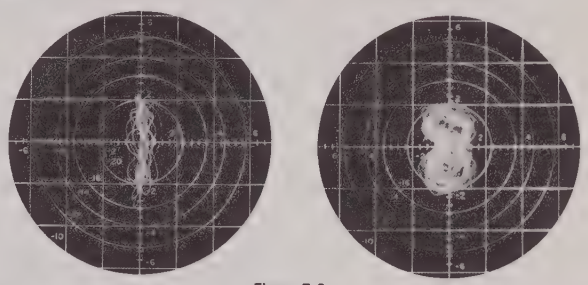

Figure 7-6

AMPLITUDE MODULATION PLUS STEADY NOISE: 10% AM at 100 Hz, plus White Noise 25 dB below tone level.
Display: Vertical dispersion exceeds horizontal dispersion.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone) plus hiss.

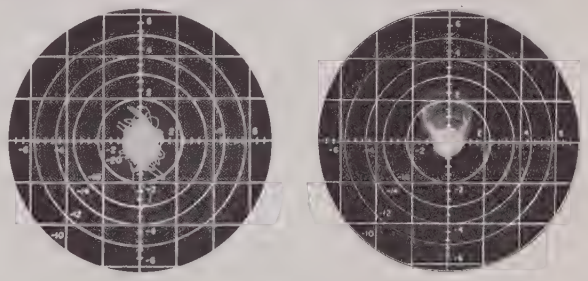

Figure 7-7

GAIN HIT PLUS STEADY NOISE: 2 dB Gain Hit with 4 millisecond rise time and 100 millisecond duration, plus White Noise 25 dB below tone level.
Display: Amplitude transient causes essentially symmetrical vertical excursion. Depending on size of hit and LEVEL ADJ setting, the DO NOT READ lamp may go on momentarily as the AGC loop moves to new level with a recovery time of 1/7 second. The UNFILTERED display circle alternately appears up and down at a rate dependent upon the duration and rise time of the hit.
Sound: Steady hiss with tone frequency double ping, one at the leading edge and one at the trailing edge of the hit. This double ping can be audibly resolved for hit durations as short as 40 milliseconds.

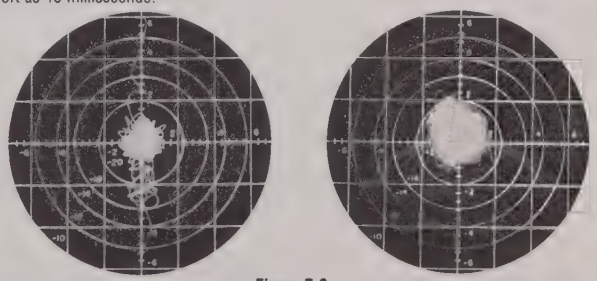

Figure 7-8

DROPOUT PLUS NOISE: 12dB, 10 millisecond fast dropout plus White Noise 25 dB below tone level.
Display: Deep vertical drop. DO NOT READ lamp goes on and remains on until after end of dropout.
Sound: Noise hiss, with loud, brief tone-frequency 'ping'. As dropouts get shorter, the ping becomes closer to the 'pop' noise of an impulse. At 2 milliseconds dropout duration, the tone component of the noise is barely distinguishable.

DISTORTION ANALYSIS IN THE UNFILTERED VECTOR NOTCH MODE

Figure 8-1

Second and Third Harmonic Distortion are visible in the UNFILTERED VECTOR NOTCH mode, but (for test tones of 800 Hz and higher) are out of the passband of the 20-300 Hz and 20-600 Hz filters. Figures 8-1 through 8-4 are thus for the UNFILTERED VECTOR NOTCH mode only. Because harmonics of the test tone are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure second harmonic forms a four-lobe cloverleaf pattern; pure third harmonic forms two nearly-coincident three-lobe cloverleaf patterns.

Figure 8-1
SECOND HARMONIC DISTORTION: Second Harmonic Distortion 30 dB below tone level.
Display: Four-lobe cloverleaf pattern, which may rotate continuously in the presence of frequency translation, move through limited angles in the case of low frequency jitter, or expand and contract in the presence of harmonic hits.
Sound: Distinctly audible second harmonic of test tone.

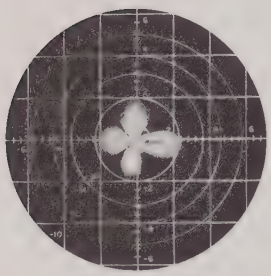

Figure 8-2

Figure 8-2
SECOND HARMONIC DISTORTION PLUS NOISE: Second Harmonic Distortion 30 dB below tone level, plus White Noise 30 dB below tone level.
Display: Same as Figure 8-1, with dispersion caused by noise.
Sound: Audible second harmonic of test tone over noise hiss.

Figure 8-3
THIRD HARMONIC DISTORTION: Third Harmonic Distortion 30 dB below tone level.
Display: Three-lobe cloverleaf pattern.
Sound: Audible third harmonic of test tone.

Figure 8-3

Figure 8-4

Figure 8-4
THIRD HARMONIC DISTORTION PLUS NOISE PLUS PHASE JITTER: Third Harmonic Distortion 30 dB below tone level, plus White Noise 30 dB below tone level, plus 10° Phase Jitter.
Display: Three-lobe cloverleaf pattern plus noise smear plus phase jitter circle pattern.
Sound: Audible third harmonic of test tone over noise hiss.

DISTORTION ANALYSIS IN THE 2ND H AND 3RD H MODES

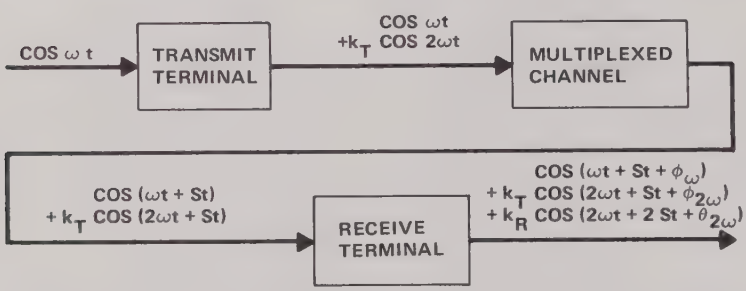
COS ω t
TRANSMIT TERMINAL
COS ωt
+k_T COS 2ωt
MULTIPLEXED CHANNEL
COS (ωt + St)
+ k_T COS (2ωt + St)
RECEIVE TERMINAL
COS (ωt + St + φ_ω)
+ k_T COS (2ωt + St + φ_2ω)
+ k_R COS (2ωt + 2 St + θ_2ω)

Figure 8-5 Sources of Second Harmonic Distortion (Simplified Analysis)

The 2ND H and 3RD H positions of the MODE switch select the second and third harmonic distortion components of the received tone for display and measurement. Figure 9-1A is a typical 2ND H or 3RD H display. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase intercept distortion of the channel. Since phase intercept distortion is an uncontrolled parameter, the deflection may be in any direction. It is therefore usually convenient to read the deflection against the circular (POLAR dB) scales. The circle calibrations are -10, -12, -14, -16, -20, and (the inner unmarked circle) -30. The POLAR dB markings of the SCALE switch indicate the number of dB to be added to (or subtracted from) the circle calibration. In the most sensitive scale position (-20 dB), the inner circle (-30 dB) corresponds to a separation of -50 dB; i.e., the harmonic level is 50 dB below the tone level.

When frequency translation is present, the phase intercept distortion angle changes continuously at a constant rate and the spot moves in a circular path, as shown in Figure 9-1B. The impairment location causing it is shown in Figure 8-5. Note that at the Receive Terminal, the frequency of distortion content, $k_T \cos(2\omega t + st)$, differs from twice the frequency of the fundamental, $\cos 2(\omega t + st)$ by the amount st. This is the equivalent of an SFI input at a beat frequency of st.

When second harmonic distortion, $k_R \cos(2\omega t + 2st)$ is introduced at the Receive Terminal, **after** the frequency translation, it is distortion of the received frequency; it is thus exactly double the received frequency and produces a stationary spot. In Figure 9-1C, note that the circle radius (k_T) corresponds to the distortion which occurs ahead of the frequency translation; the offset (k_R) of the center of the circle corresponds to the distortion which has occurred after the frequency translation; and the rate at which the circle is traversed by the spot is a measure of the frequency translation. The foregoing analysis may be extended to third harmonic distortion.

There may be multiple frequency translation sources as well as other phenomena which cause variations in the phase intercept distortion angle. Phase hits cause intermittent angular motion of the spot. Phase modulation causes oscillatory angular motion of the spot. Filters limit the display bandwidth in the harmonic modes so that only low-frequency jitter can be thus observed. There may also be harmonic amplitude hits, usually involving PCM carrier, which cause radial motion of the spot. There are normally multiple distortion sources although in a trouble situation, usually one will predominate. These phenomena may occur at any voice appearance in the transmission path, with unpredictable phase intercept distortion between their point of generation and the final output. The result is spot motion in random directions. The operational significance of the above is that if the distortion spot displays high mobility it is an indication that the channel will have trouble passing data.

A B C

Figure 9-1 Typical Displays in the 2nd H and 3rd H Modes

PHASE INTERCEPT DISTORTION

The time delay for any frequency component passing through a transmission medium is the slope of the line joining that point on the curve with the origin on a phase vs. frequency plot. One condition required for undistorted transmission of a complex wave shape is that the phase vs. frequency curve (plotted in linear units, and extrapolated down to DC) be a straight line passing through the origin. This is the response corresponding to a pure time delay. The slope of this line is the time delay, t. Dimensionally ϕ/ω = t; Radians/(Rad/Sec) = Sec. Intuitively there is no time domain waveshape distortion because all frequency components have the same time delay and therefore arrive in the same relative phase at the far end as they leave at the near end.

Note that a perfectly linear phase vs. frequency curve (zero envelope delay distortion) is not a sufficient condition for low baseband distortion because (Figure 9-2) the component of frequency ω_1 has a time delay ϕ_1/ω_1 which is entirely different from that of the ω_2 component, ϕ_2/ω_2.This distortion is a result of the intercept angle ϕ_0, of the extrapolated phase vs. frequency curve, at zero frequency. This is known as the phase intercept distortion. It is an uncontrolled parameter in most communications systems.

The angular displacement of the spot for either second or third harmonic distortion measurement is a measure of the phase intercept distortion. In the mechanization of the instrument, the received tone, cos ($\omega t + \phi_\omega$) is tracked. It is then doubled, i.e., cos ($2\omega t + 2\phi_\omega$).

The phase and amplitude of the second harmonic cos ($2\omega t + \phi_{2\omega}$) is plotted with respect to the double frequency tone as a reference. Referring to Figure 9-3 which is a phase vs. frequency plot, the phase difference between cos $2(\omega t + \phi_\omega)$ and cos ($2\omega t + \phi_{2\omega}$) is ($2\phi_\omega - \phi_{2\omega}$). This is the deflection angle of the harmonic distortion spot. It is also the phase intercept distortion based on measurement at frequencies ω and 2ω. A similar observation is true with respect to the third harmonic.

Angular motion of the harmonic spot corresponds to changes in phase intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase intercept distortion due to that source. However, a multiplicity of distortion sources may exist in a transmission channel relative to a multiplicity of phase intercept distortion sources. The case of frequency translation described above is commonly encountered.

The measurement is limited by the filter bandwidth. This must be narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50 dB below signal level). Where it is desired to study the phase intercept distortion, a harmonically rich signal can be transmitted (TEST SOURCE position of OUTPUT SELECT switch). This raises the harmonic level above the normal noise level. Filter bandwidth can also be increased, by an optional internal modification to the PB-1.

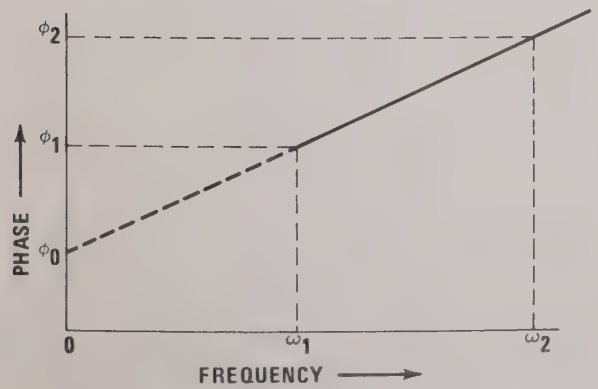

Figure 9-2 Definition of Phase-Intercept Distortion

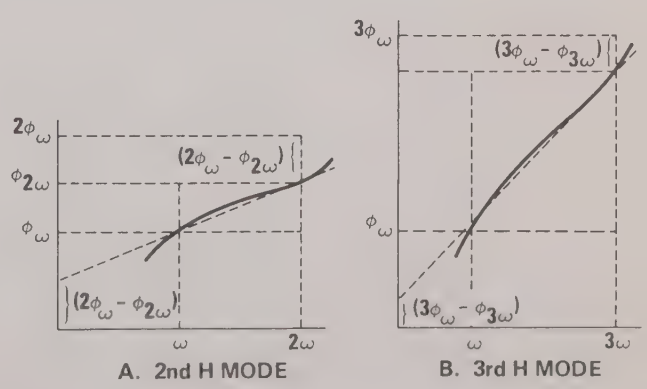

Figure 9-3 Quantities Measured in 2nd H and 3rd H Modes

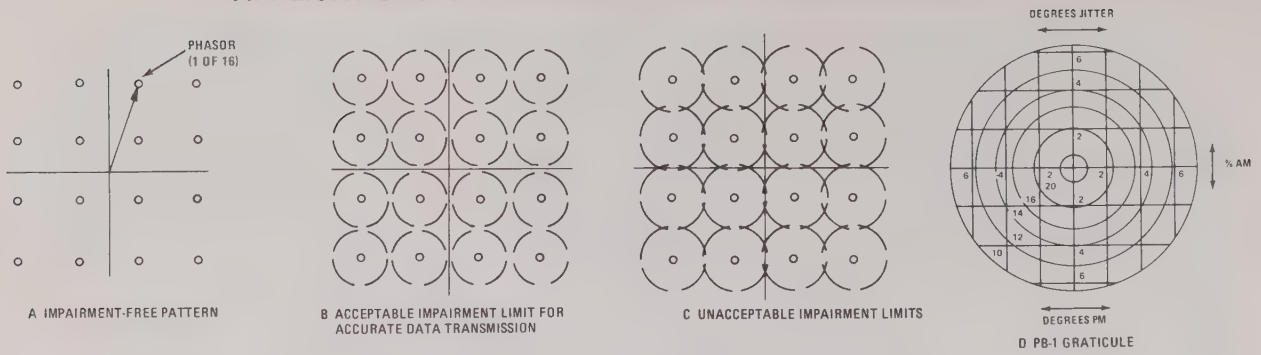

Figure 10-1 Permissible Disturbance Areas Around Decision Points in a QAM Modem

GO/NO-GO EVALUATION OF LINE-MODEM COMPATIBILITY

High-speed digital data is transmitted over voice-frequency channels by synchronous modems employing phase and/or amplitude modulation of audio-frequency carriers or 'clocks'. The receiving modem 'recovers' the clock frequency from the transmitted signal; i.e., synchronizes to that clock frequency. Relatively small line impairments can cause errors in such modems; large line impairments can cause momentary loss of synchronization.

A synchronous modem transmits N bits of binary data per cycle of a clock frequency by sending one of 2^N encoded states of phase and/or amplitude modulation of that clock frequency, and changing the state once each clock cycle. For example, 16 possible states of the clock frequency may be represented by 16 phasors, as shown in Figure 10-1A. This type of coding is called QAM, denoting an encoding scheme combining both Quadrature and Amplitude Modulation. The entire area of Figure 10-1A represents the modem 'decision space'; the 'constellation' or 'eye' pattern of 'decision points' represents the locations of the tips of the 16 phasors.

Line disturbances occurring at any instant during transmission of any phase-and-amplitude-modulated signal will add vectorially to that signal, shifting the tip of the phasor being transmitted at that instant, so the receiving modem will not see the 16 stationary points of the constellation pattern, but will see smeared areas around the theoretical points. The receiving modem can operate without error only if adjacent smeared areas do not overlap. As shown in Figure 10-1B, it is possible to define a geometric figure bounding the maximum permissible area within which errors will not occur. Disturbances causing overlapping smears, as in Figure 10-1C, will cause errors. Note that the permissible area must frequently include an allowance for harmonic distortion which is measured separately, as explained below, and an allowance for the phasor tip smear resulting from static line impairments such as gain and envelope delay distortion.

When a test tone is transmitted over a voice-frequency channel, line disturbances will add vectorially to the tip of the received tone phasor and smear that tip over an area, in exactly the same way as they would smear the tips of the 16 QAM phasors over 16 areas in the modem decision space. If the received tone is examined by a PB-1 VF Line Analyzer, the steady-state tone is suppressed so that (in the VECTOR NOTCH mode) the disturbances can be displayed on an expanded basis, as shown in Figure 10-1D. This is equivalent to continuous high-resolution examination of a single modem decision point. It can immediately be determined whether the line disturbances remain within the permissible area (GO condition) or extend beyond the permissible area (NO-GO condition). The PB-1 views all the instantaneous components of peak noise, thereby identifying not only disturbances which have been classified and are now measured by conventional test equipment, but also disturbances that have not yet been classified, and which are now ignored, even though they affect modem performance.

Because the frequency content of a modem signal may extend beyond one octave, and because harmonic distortion modifies the decision space, the line-evaluation procedure should include measurements of 2nd and 3rd harmonics. The PB-1, by measuring (in the VECTOR NOTCH mode) the in-phase and quadrature components of disturbances, and (in the 2ND H and 3RD H modes) the harmonic distortion, defines line performance with respect to modem requirements.

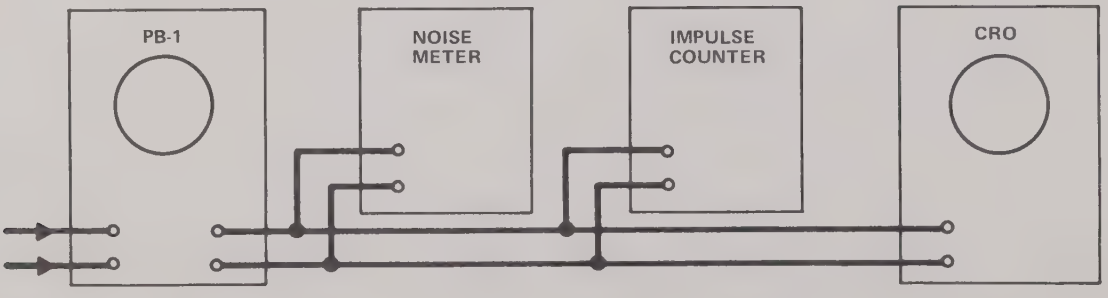

Figure 10-2 PB-1 VF Line Analyzer as a Tracking Notch Filter

TRACKING NOTCH-FILTER FOR OTHER INSTRUMENTS

Since the PB-1 tracks and suppresses the steady-state component of received tone, leaving only the disturbances on that tone as 'notched noise' to be analyzed and displayed, it acts as an extremely narrow-band notch filter that can track any one of five input tones (404, 804, 1004, 1704, and 2804 Hz) over a ± 8% frequency range. The notched noise is available as an electrical output for use by other instruments, as shown in Figure 10-2. When fed to conventional noise meters, the notched-noise output causes those meters to operate as notched noise meters. The same output permits impulse counters to operate on lines in the presence of holding tones without being triggered by those tones. The notched noise can also be fed to the vertical input of a cathode-ray oscilloscope for display in the time domain.

UNATTENDED MONITORING OF LINE IMPAIRMENTS

A number of useful voltages derived by the PB-1 from the input signal are available at a nine-pin connector on the rear of the instrument. When fed to a multi-channel strip-chart recorder or tape recorder, as shown in Figure 11-1, these outputs permit unattended monitoring of line impairments. The recorded data may be analyzed at leisure, and used to prove the existence of various line impairments. Note that the Horizontal Deflection Voltage at Pin A and the Vertical Deflection Voltage at Pin B are selected for display by the MODE switch. Depending on the position of that switch, these outputs may represent Input LEVEL, dBm (same as on Pin H), VECTOR NOTCH components (same as on Pins D and E), the in-phase and quadrature components of 2ND Harmonic Distortion, the in-phase and quadrature components of 3RD Harmonic Distortion, and a voltage proportional to Percent Frequency Deviation.

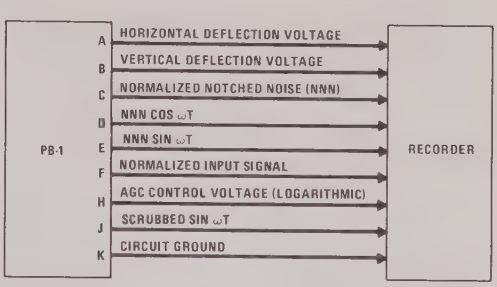

Figure 11-1 PB-1 Outputs for Monitoring, Recording or Remote Display

EVALUATING DUAL DIAL BACKUP LINES

The PB-1 can simplify and expedite the procedure of establishing a two-way Dial Network backup for private or leased lines between a near terminal and a marginally-attended or unattended far terminal, by reducing the problem from that of simultaneously finding two acceptable lines at each dialing to that of finding one acceptable line at each dialing.

When either or both of a pair of private or leased lines fails to transmit data satisfactorily between a near or local terminal and a far or remote terminal, it is common to use the Dial Network as a backup, by dialing two lines between the terminals for full duplex operation. To be certain that the two backup lines are useable in the intended directions of use, they must be checked out in those directions. Assuming that the means of verifying good lines is at the near terminal, the lines are looped back at the far terminal, and digital data (in the case of digital loopback) or a test tone (in the case of analog loopback) are sent around the loop from and to the near terminal. If the looparound signal is not satisfactory, two new lines are dialed and the test is repeated, until a satisfactory loop is obtained. Note that two lines must be rejected if the loop is not acceptable, even though one of the lines may be good. This necessitates dialing and testing until two simultaneously acceptable lines are found.

The PB-1 permits one satisfactory line be found at each attempt, as follows. The far-end transmit line is dialed and the far end sends a tone along this line to a PB-1 at the near end (Figure 11-2A). If the PB-1 indicates that the line is not satisfactory, alternate lines are dialed and tested until the PB-1 indicates that a line is satisfactory. That line is held, and the far-end receive line is dialed. This line is looped to the far-end transmit line, and the near end sends a tone through the loopback to the PB-1 (Figure 11-2B). Since the far-end transmit line is known to be good, only far-end receive lines need be dialed, until the PB-1 indicates that the loopback is good. Once the return path has been established as acceptable by the remote oscillator and local PB-1, the loopback test can alternatively be performed on a digital basis.

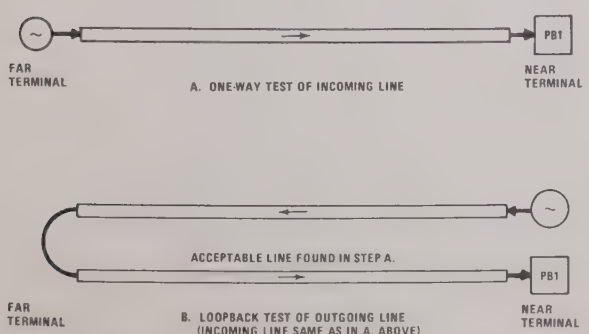

Figure 11-2 Evaluating Dual Dial Backup Lines

IDENTIFICATION OF FACILITIES BY SIGNATURES

The time constants of the AGC loop and of the Phase-Lock Loop are such that both loops operate rapidly enough to recover from transients within the 1/7 second dead-time interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients. The PB-1 therefore responds to transients in ways that identify them acoustically. Gain or phase hits 'pull' the tracking loops, thus momentarily degrading the notch, and causing a 'ping' as the tone 'leaks' through during the recovery period. Low-frequency steady-state modulation also pulls the loops, causing a 'wow'. Impulse hits do not pull either tracking loop; they cause a 'pop'.

The PB-1 visual and acoustic outputs frequently permit identification of telephone transmission facilities through which the test tone may pass. FDM, PCM, and Copper facilities have characteristic impairment patterns which frequently permit identification. Although there is no substitute for extended experience in using the PB-1 to develop facility identification capability, the following represent a starting point.

FDM (Figures 7-2, 7-3, and 7-4)
Patterns in which phase jitter predominates usually indicate that FDM is involved. Low-frequency jitter is characteristic of older FDM's. Continuous small phase hits, visible and audible, order of magnitude a few degrees, are an indication the facility is passing through the heavy traffic area. Circular motion or high angular mobility of the harmonic distortion spot frequently indicates sync supply problems.

PCM (Figures 7-6, 8-2, and 8-4)
Vertical excursion (amplitude jitter) exceeds horizontal, and harmonic distortion frequently is much larger than in FDM channels, particularly in older channel banks. VECTOR NOTCH pattern is sensitive to test tone frequency. Tone sources at 1000 Hz may result in an aliasing product near 3 khz which moves the 3rd harmonic spot dramatically. Characteristic grinding sound. Excessive distortion and large radial steps in distortion spot (particularly third harmonic) may indicate timing problems.

Copper (Figures 6-2 and 6-3)
No modulation impairments of any kind.

CHECKING QUALITY OF TEST-TONE SOURCES

It is advisable to use the PB-1 to check station test-tone sources initially and periodically. This is done by patching the PB-1 directly to the tone source and observing the source output with maximum sensitivity in the VECTOR NOTCH, 2ND H, and 3RD H modes. This assures that when a test-tone source is used for testing transmission channels, there are no disturbances (i.e., harmonics, level and/or frequency shifts, phase and/or amplitude modulation, hum, noise, etc.) on the test tone that would be erroneously attributed to the transmission channels under test.

IMPLICATIONS OF THE SUPPRESSED-TONE PHASOR-DISPLAY TECHNIQUE

The single most significant fact about the suppressed-tone phasor-display technique is that it permits a meaningful display of all impairments over the entire VF spectral range at one time. Such a presentation in the time domain or the frequency domain is not meaningful because the information is not comprehensible. Early users of the PB-1, primarily Bell System engineers, were quick to notice that, using the PB-1 as the translating device between facility and craftsman, not only do relationships between presently defined impairments become clear, but previously unobserved impairments become apparent. Impairments are shown in real time as they actually happen, so that it is possible to clear or tag a facility in a matter of minutes. In the VECTOR NOTCH, UNFILTERED mode, the PB-1 display includes the entire voice band, except for the notch region within ±1 Hz of the test tone. The information is classified in the QAM plane, a classification which shows phase relationships between impairments and tone more clearly than any other measurement or display technique. Phase relationship information pinpoints fault location in a facility because it permits noise, modulation, and harmonic distortion disturbances to be resolved by inspection. As a result, the PB-1 has quickly become a 'microscope' for the examination of facility performance from an entirely new and informative viewpoint.

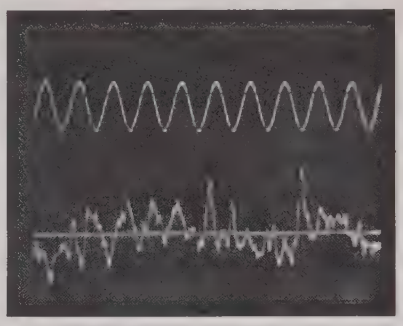

Figure 12-1 Two Waveforms Having Equal RMS Values

Limitations of Existing Practice

Conventional transmission channel instrumentation reduces tone impairments to sets of numbers. To accomplish this the impairments are filtered, detected by one of a variety of detectors, e.g., average value, rms, quasi-rms, peak, etc., time averaged, and displayed as a numerical result. Transient phenomena are also monitored in this pattern. The time-averaging interval typically becomes 15 minutes, and the detector a presetable analog threshold level detector with artfully defined criteria for hit duration, hit rise time, and hit interval. The problems with such measurements are as follows:

1. It is virtually impossible to convert two-dimensional time-varying and/or random quantities into a set of numbers of any reasonable set size. Information is necessarily lost in the process.

2. Any set of rules for converting the information into numbers, no matter how artfully chosen, can represent only what is generally the case for known phenomena. Exceptional cases and unrecognized impairments are frequently hidden. It is accepted that the results will be misleading in some small percentage of cases. Nevertheless exceptions and 'new' impairments always come as a surprise, and they result in those occasional long-duration and costly maintenance efforts which continue interminably until someone recognizes the hole in the definition through which the impairment has slipped.

3. A costly characteristic of the presentation of purely numerical results is obsolescence. From time to time new impairments are defined, and the classification rules for existing impairments are changed, as a result of new data set requirements, new tariffs, new facilities, and/or discovery of new phenomena. When this happens, existing test equipment, which mechanizes elaborate existing rules, becomes obsolete. This is less often the case for instrumentation such as the PB-1, which imposes a minimum of such rules.

Notched Noise, An Example

As an example of the effect of instrument mechanization rules on information content, consider C-message-weighted notched noise. Notched noise is what remains after the tone is removed. It includes additive noise, modulation impairments, and harmonic distortion impairments. Because it includes all disturbances, notched noise is the single most meaningful existing impairment parameter for evaluation of facility/modem compatibility. This has been recognized in the Bell System 'D' tariff, which essentially specifies rms notched noise and non-linear distortion.

RMS noise is a measure of the energy content of disturbances. It is the all-important quantity when rms detectors, such as ears, are involved. As channel bandwidth is used more effectively however, the requirements on disturbances become more stringent. For synchronous modems, making several thousand multi-state analog threshold decisions per second, disturbance sensitivity is more closely measured by instantaneous (peak) noise rather than by rms noise. Further, the sensitivity of synchronous modem error rates to modulation impairments is determined by the modem encoding scheme; e.g., phase-encoded modems are only marginally susceptible to amplitude disturbances.

The typical noise measurement is C-message weighted, a weighting which discriminates heavily against power line frequencies. The signal is weighted by a specific bandpass filter. The test tone is removed with a narrowband reject (notch) filter. The remainder is detected with an rms or quasi-rms detector, the output of the detector is averaged with a specified fractional-second-averaging time constant, and the result is displayed as a number. Since the number is in dBm or dBrn, a logarithmic element is included. The following information is removed by the above set of rules

1. Crest Factor. This is the ratio of peak to rms noise. It is highly waveshape dependent (Figure 12-1). The 'spikiness' of the noise is completely masked in an rms measurement.

2. Phase Relationship of Impairments to Tone. Phase modulation or amplitude modulation may, depending upon the nature of the modem encoding scheme, be less harmful than random noise.

3. Harmonic Relationship of Impairments to Tone. Certain harmonics are more significant in data impairment than their contribution to rms noise.

4. Phenomena near the tone frequency, such as low frequency modulation impairments, will be attenuated or eliminated because of the bandwidth permitted in the notching (band reject) filter.

However, if the noise is 'typical' in character, i.e., the large majority of cases, the measurement result is valid for establishing facility/modem compatibility. If the noise is unusually 'spikey', if low frequency modulation is present, if an SFI tone near the modem clock frequency is present, or if the impairment is entirely in the 'wrong' direction (e.g., phase modulation on a facility which is to be used with a phase-encoded modem), the line may not move data. On the other hand if the impairment is primarily SFI remote from the modem clock frequency, or is primarily in the 'right' direction (e.g., amplitude modulation on a facility which is to be used with a phase-encoded modem), the measurement result may be unduly conservative.

New Information

The suppressed-tone phasor-display technique provides two new kinds of information. One of these is information about defined phenomena which is rejected by conventional instrumentation because of the mechanization rules. This includes phenomena such as:

1. Phase Jitter. Because it was 'discovered' as a problem after the advent of vestigal-sideband and phase-encoded modems, phase jitter is not a voice-technology-based measurement; as a result, it is defined on a peak to peak basis. However, prior to the PB-1's existence it was not possible to resolve phase modulation and the effects of noise on phase. These quantities were therefore lumped and called phase jitter. In order to minimize the effects of noise on the reading, the bandwidth of impairments examined was restricted to the region between 20 and 300 Hz around the test tone. As might be expected, due to the natural perversity of things, significant incidental phase modulation exists outside this range.

2. Notched Noise. See discussion above.

3. Transient Phenomena. This is perhaps the least defined area of all. It is necessary to define rise time, duration, interval, and phase coherence (phase hits and gain hits are phase coherent: impulse hits are not) in order to 'count' a hit. These quantities vary continuously in the real world. Hits which are below threshold or are too slow in transition, too brief, or occur too soon after previous hits are ignored. For any of these reasons, either of two hits which differ only slightly may be counted while the other hit may be ignored.

4. Amplitude Jitter. Not now routinely measured.

The second new kind of information, which is associated with the harmonic modes, is the measurement of phase intercept distortion (See page 9). This is another one of the normally unmeasured quantities which characterizes a significant fraction of the 'mystery' problems, i.e., channels which meet published requirements but which will not pass data.

DESCRIPTION OF PB-1 VF LINE ANALYZER

2-1. EXTERNAL DESCRIPTION

2-2. The PB-1 is contained in a portable case with a wraparound cover that projects forward over the front panel and backward over the rear panel. On the underside of the instrument are a loudspeaker for audio output, and a bail or tilt stand that permits the front of the instrument to be tilted up for ease of viewing the CRT display and the operating controls. The unit is 5 3/8" wide, 10" high, and 14 1/2" deep.

2-3. The PB-1R is a rack-mounting version of the PB-1. The 19-inch wide panel is notched for all electronic and telephone racks and enclosures, and occupies only 7 inches of vertical space. The PB-1R panel has a cutout for mounting a PB-OR test signal oscillator.

2-4. FRONT PANEL

2-5. The PB-1 Front Panel is shown in Figure 2-1.

a. The screen, bezel and graticule of 3-inch cathode-ray tube (CRT) are located at approximately the center of the panel.

b. Above the CRT are three controls (INTENSITY, FOCUS and SCALE ILLUM), three rotary selector switches (JITTER DISPLAY, FILTER RANGE and NOMINAL FREQUENCY), and a DO NOT READ indicator lamp.

c. Immediately below the CRT is a horizontal row of three rotary selector switches (LEVEL ADJ, MODE, and SCALE).

d. At the bottom left is a group of INPUT terminals, an input termination selector switch, and (optionally) a HOLD COIL toggle switch.

e. At the bottom center is a group of OUTPUT terminals, an OUTPUT LEVEL toggle switch, and an OUTPUT SELECT rotary switch.

f. Between the INPUT and OUTPUT terminals is a banana jack that is connected to circuit ground.

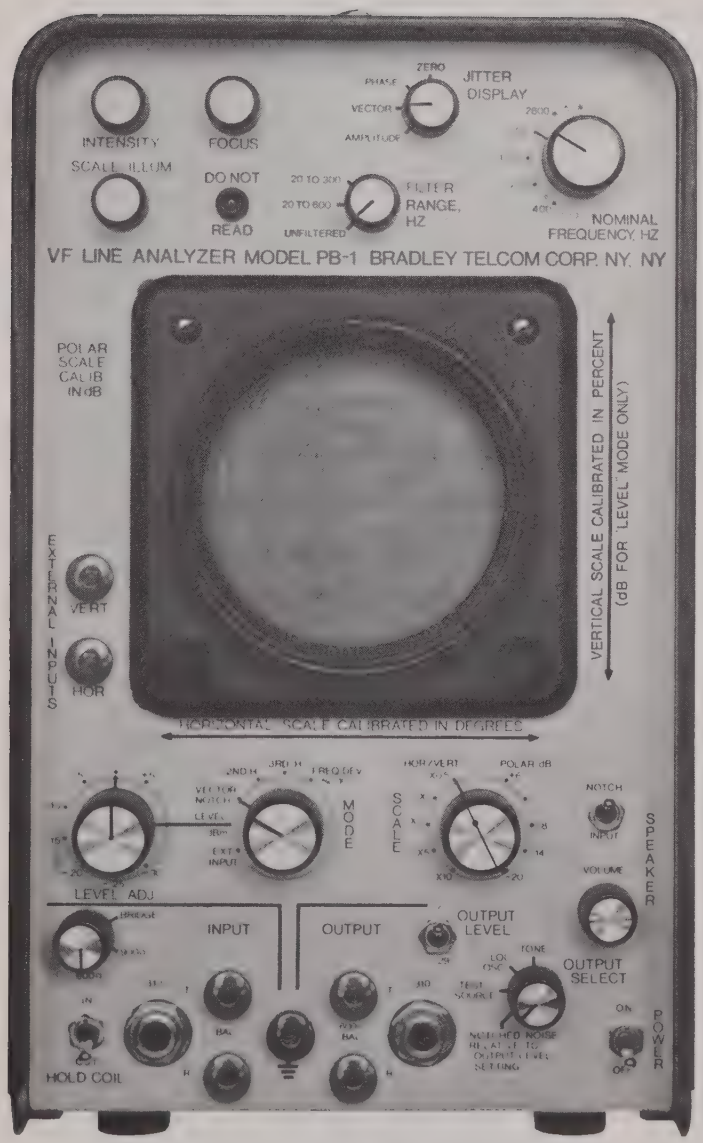

Figure 2-1 PB-1, Front Panel

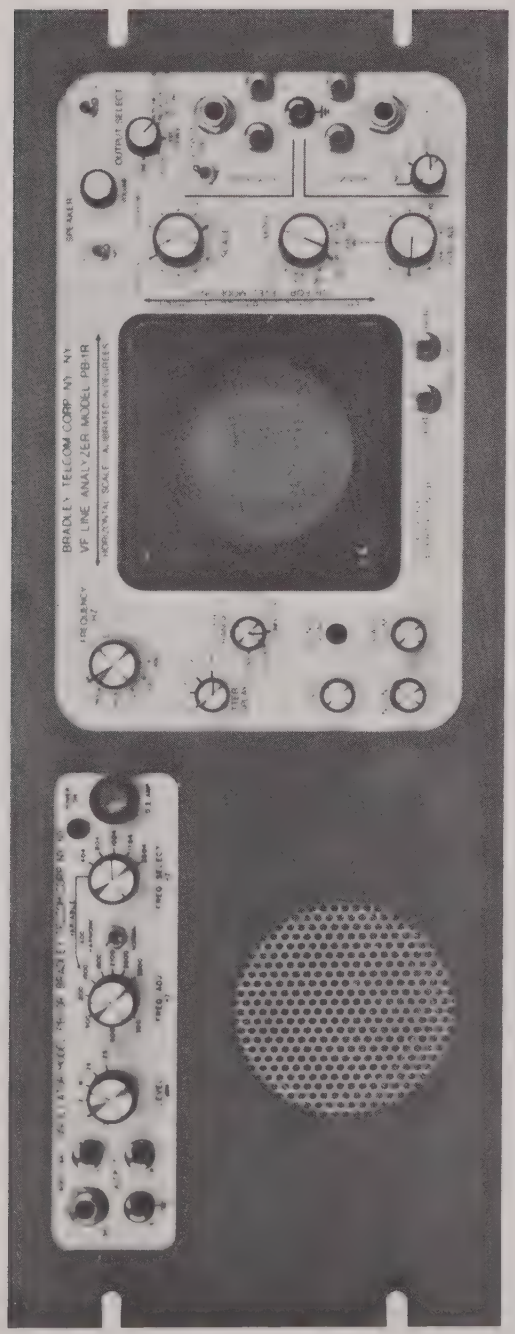

Figure 2-2 PB-1R, Front Panel

g. Along the lower right side of the panel are two SPEAKER controls (NOTCH/INPUT toggle switch and VOLUME control) and a main POWER ON/OFF toggle switch.

h. At the left of the CRT are two EXTERNAL INPUT terminals labeled VERT and HOR.

2-6. Regardless of the physical location of the various panel controls and terminals, they are associated in the various functional groups, namely, Input, Display, Speaker, and Output, described in the paragraphs below.

2-7. INPUT Controls and Terminals

2-8. Two input banana jacks labeled T and R are spaced vertically to accept standard double banana plugs. These jacks have selectable balanced input impedances of 600, 900 or 30,000 Ohms (depending on the setting of the input termination switch), and accept balanced or unbalanced test tones at levels between +9.5 dBm and -34.5 dBm (depending on the setting of the LEVEL ADJ selector).

2-9. An input phone jack next to the input banana jacks has its tip and ring connected to the T and R banana jacks respectively, and its sleeve connected to the ground banana jack between INPUT and OUTPUT sections. The phone jack accepts PJ051/WE310 phone plugs. The input impedances and acceptable input test tone levels are identical to those of the input banana jacks.

2-10. The grounded banana jack between the INPUT and OUTPUT groups may be used to ground the input R banana jack and the ring of the phone jack, when it is desired to connect the input T banana jack or the tip of the input phone jack to an unbalanced input. Similarly, the ground jack may be used to ground the output R banana jack and the ring of the output phone jack, when it is desired to connect the output T banana jack or the output phone jack to an unbalanced load.

2-11. The input termination selector switch permits selection of balanced 600Ω, 900Ω, or BRIDGING (30,000 Ohm) input impedances for all input jacks.

2-12. The HOLD COIL toggle switch and a holding coil compatible with 48 VDC central office batteries are a factory-installed option. When the switch is set to IN, the holding coil is connected across the input terminals of the PB-1, and thus across the input line; when the switch is set to OUT, the holding coil is disconnected.

2-20. Note. To avoid burning center of screen, if spot remains undeflected for long period, reduce setting of INTENSITY control. Do not change setting of FOCUS control, even though the reduced-intensity spot may be defocused. When intensity is increased to former level, spot will again be in focus.

2-21. The SCALE ILLUM control permits continuous variation of the brightness of the graticule scales.

2-22. The graticule mounted in front of the cathode-ray-tube screen has three sets of illuminated scales that permit measurements of the various types of input signal displays selected by the MODE switch. The graticule scales are calibrated as follows:

a. The vertical scale is divided by equally-spaced horizontal lines that are numbered along the vertical axis from bottom to top, as follows: -6, -4, -2, (0), +2, +4, and +6. As noted by the legend at the right of the CRT bezel, the vertical scale numbers represent percent for all positions of the MODE selector except the LEVEL position, for which the vertical scale numbers represent dBm.

b. The horizontal scale is divided by equally-spaced vertical lines that are numbered along the horizontal axis from left to right as follows: -3, -2, -1, (0), +1, +2, and +3. As noted by the legend immediately below the CRT bezel, the horizontal scale numbers represent angular degrees.

c. The polar scale is divided by concentric circles that are numbered along a diagonal from lower left to center as follows: -10, -12, -14, -16, and -20. The innermost circle, representing -30, is not numbered on the graticule. As noted by the legend near the upper left of the CRT bezel, the polar scale numbers represent dB.

2-23. The MODE switch is a rotary selector switch having six positions labeled EXT INPUT, LEVEL (dBM), VECTOR NOTCH, 2ND H, 3RD H, and FREQ DEV, %/10. Each of these represents a display mode.

a. In the EXT INPUT mode, the HOR and VERT EXTERNAL INPUT banana jacks near the lower left of the CRT bezel are connected to the CRT deflection circuits through the SCALE switch, permitting the PB-1 to be used as an X-Y oscilloscope or vectorscope to display modem 'eye'

patterns, 'constellation' patterns, or decision spaces. Many modems have X-Y outputs for this purpose. Both HOR and VERT EXTERNAL INPUT jacks have the same nominal deflection sensitivities, which are related to the SCALE switch settings as follows:

SCALE switch setting	X0.5	X1	X2	X5	X10
EXT INPUT sensitivity,mV/cm	50	100	200	500	1000

b. In the LEVEL (dBm) mode, the dBm level of the input test tone can be read as the sum of the CRT vertical deflection (taking into account the SCALE multiplication factor) and the setting of the LEVEL ADJ switch. With the SCALE switch at the lowest sensitivity setting of X10, the LEVEL ADJ switch is rotated until the DO NOT READ lamp goes off, and the CRT spot appears on the screen. The SCALE switch is then set to X1, so that the vertical deflection of the spot can be read directly in dBm. This spot deflection value is added algebraically to the LEVEL ADJ switch setting to give the input tone level in dBm.

c. In the VECTOR NOTCH mode, the steady-state received tone is suppressed and various aspects of the remaining 'notched noise' are displayed, depending on the settings of the JITTER DISPLAY and FILTER RANGE switches.

d. In the 2ND H mode, the amplitude and phase of components of the notched noise near twice the frequency of the received tone are displayed, as shown in Figure 2-4.

e. In the 3RD H mode, the amplitude and phase of components of the notched noise near three times the frequency of the received tone are displayed, as shown in Figure 2-4.

f. In the FREQ DEV %/10 mode, the percent deviation of the actual frequency of the received tone from the specified value (i.e., 404, 804, 1004, 1704, 2804 and f6 Hz) is displayed as a vertical deflection. Note that in this mode the deflection must be multiplied by one-tenth of the scale factor indicated by the setting of the SCALE switch. Thus, when the SCALE switch is set to X10, the vertical deflection is direct reading in percent frequency deviation.

2-24. The SCALE control is a five-position rotary selector switch. The control knob has a diametral line engraved across its top, so that it simultaneously indicates one HOR/VERT scale factor to the left, and one POLAR dB scale factor to the right. The corresponding HOR/VERT and POLAR dB scale factors for each of the five positions are:

HOR/VERT	X0.5	X1	X2	X5	X10
POLAR dB	-20	-14	-8	0	+6

a. The horizontal scale on the graticule is numbered ±(1, 2, 3), and the vertical scale is numbered ±(2, 4, 6). The horizontal scale represents angular degrees, and the vertical scale represents percent in change in all modes except the LEVEL dBm mode (in which the vertical scale represents dB). Although the horizontal and vertical scales represent different units, the same SCALE switch HOR/VERT multiplication factors apply to both simultaneously, as shown in the table below.

			SCALE Switch HOR/VERT Setting				
			X0.5	X1	X2	X5	X10
Graticule Reading	Horizontal	1	0.5	1	2	5	10
		2	1.0	2	4	10	20
		3	1.5	3	6	15	30
	Vertical	2	1	2	4	10	20
		4	2	4	8	20	40
		6	3	6	12	30	60

b. Phenomena such as gain hits and gain steps are displayed as vertical deflections in percent, but are customarily referred to in dB relative to the tone amplitude. Figure 2-3 is a plot of the relationship between percent change and dB change.

c. The graticule circles used for the POLAR dB are calibrated in -10, -12, -14, -16, -20, and -30 dB from the outermost to the innermost. All but the innermost are numbered. Since the calibrations of the circles represent dB relative to the POLAR dB setting of the SCALE switch, the dB value at each setting of the SCALE switch must be added algebraically to the graticule circle values.

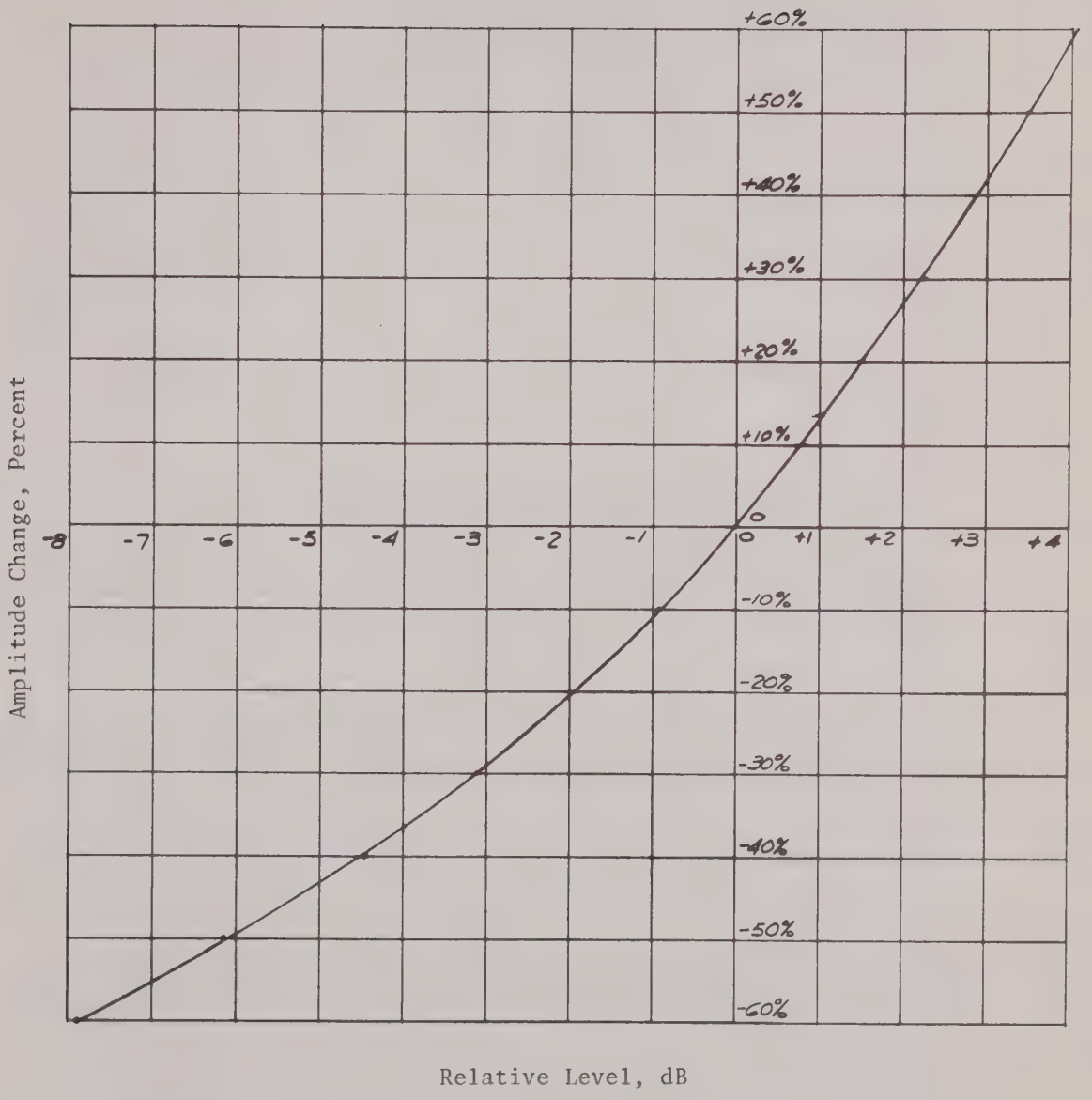

Figure 2-3 Conversion From Percent to dB

The following table shows how the POLAR dB setting and the graticule reading are added to give the total level in dB of any deflections.

Graticule Reading	SCALE Switch POLAR dB Setting				
	-20	-14	-8	0	+6
-30	-50	-44	-38	-30	-24
-20	-40	-34	-28	-20	-14
-16	-36	-30	-24	-16	-10
-14	-34	-28	-22	-14	- 8
-12	-32	-26	-20	-12	- 6
-10	-30	-24	-18	-10	- 4

2-25. The FILTER RANGE control is a rotary selector switch having three positions labeled 20 to 300, 20 to 600, and UNFILTERED. The FILTER RANGE switch is operational only in the VECTOR NOTCH position of the MODE SWITCH, when it determines the bandwidth of the Normalized Notched Noise displayed on the CRT. Figure 2-4 shows the bandwidths of the VECTOR NOTCH display for each of the three FILTER RANGE settings.

2-26. The JITTER DISPLAY control is a rotary selector switch having four positions labeled AMPLITUDE, VECTOR, PHASE, and ZERO. These are operational only in the VECTOR NOTCH position of the MODE switch.

a. In the VECTOR position, both the horizontal and vertical components of the Normalized Notched Noise are displayed.

b. In the AMPLITUDE position, the CRT horizontal input is grounded, so that only the vertical (amplitude jitter) component of the Normalized Notched Noise is displayed.

c. In the PHASE position, the CRT vertical input is grounded, so that only the horizontal component (phase jitter) of the Normalized Notched Noise is displayed.

d. In the ZERO position, both the horizontal and vertical components of the suppressed-tone phasor are grounded, so that the CRT spot may be centered by means of the HOR and VERT ZEROING adjustments accessible through holes in the rear panel.

2-27. SPEAKER Controls

2-28. The SPEAKER toggle switch has two positions labeled INPUT and NOTCH. In the INPUT position, the received tone is fed to the loudspeaker. In the NOTCH position, the Normalized Notched Noise is fed to the loudspeaker. This acoustic output is a valuable aid in identifying certain types of impairments by means of their characteristic 'signatures'.

2-29. The SPEAKER VOLUME control permits adjusting the acoustic output level of the loudspeaker.

2-30. OUTPUT Controls and Terminals

2-31. Two 600Ω BAL output banana jacks labeled T and R are spaced vertically so as to accept standard double-banana plugs.

2-32. An output phone jack next to the 600Ω BAL output banana jacks has its tip and ring connected to the T and R banana jacks respectively. This phone jack accepts WE310/PJ051 phone plugs. The output impedance and level are the same as for the 600Ω BAL output banana jacks.

2-33. An OUTPUT LEVEL toggle switch permits selection of an output signal level of either 0(dBm) or -29(dBm) when the output jacks are terminated with a 600 Ohm load. The output levels will be different if the termination is other than 600 Ohms.

2-34. The OUTPUT SELECT is a rotary switch having four positions labeled TONE, LOC OSC, TEST SOURCE, and NOTCHED NOISE RELATIVE TO OUTPUT LEVEL SETTING. In the TONE mode the local oscillator is free running; in the other three modes, the local oscillator tracks the input tone.

a. In the TONE position of the OUTPUT SELECT switch, the phase-lock loop is opened and the free-running local oscillator is connected to the OUTPUT terminals. The output frequency will be 404, 804, 1004, 1704, 2804 and f6 Hz, all ±0.25%, as selected by the NOMINAL FREQUENCY switch. The PB-1 will not track an input tone in the TONE mode, but will function only as a test oscillator.

b. In the LOC OSC position, the voltage-controlled oscillator (VCO) of the phase-lock loop tracks the input tone. The VCO output is fed to the output terminals. The output, therefore, repeats the input frequency, but is 'scrubbed' or noise-free, since the phase-lock loop acts as a narrowband filter tuned to the input frequency.

c. In the TEST SOURCE position, the output is the voltage-controlled oscillator tone when tracking the input, as in b. above, but with a large harmonic content.

d. In the position labeled NOTCHED NOISE RELATIVE TO OUTPUT LEVEL SETTING, the output is the received signal with the test tone removed or 'suppressed'. This is called 'notched noise'. In this mode, the phase-lock loop acts as a notch or suppression filter that tracks the input over a ±8% range with respect to the nominal frequency. The notch depth is 50 dB and notch 3 dB bandwidth is ±3 Hz.

2-35. The PB-1R Front Panel is shown in Figure 2-2. The panel has cutouts for the PB-1R, for a loudspeaker, and for an optional PB-OR oscillator. The PB-1R is mounted sideways at the right side of the panel. The loudspeaker for acoustic output (which in the PB-1 is mounted in the bottom of the unit) is mounted at the bottom left of the panel. At the top left is a horizontal rectangular cutout in which may be mounted the optional PB-OR oscillator.

2-36. REAR PANEL

2-37. The PB-1 Rear Panel has two small holes at the top for HOR and VERT ZEROING adjustments. At the bottom of the rear panel is a cutout through which appear, from left to right, an OUTPUT CONNECTOR, the AC power connector and a FUSE post containing a replaceable 0.5 Ampere slow-blow cartridge fuse. Four knobs on the rear panel permit the power cord to be wrapped securely when not in use.

2-38. The screwdriver-adjusted HOR ZEROING and VERT ZEROING potentiometers are used to center the CRT spot when the MODE switch is set to VECTOR NOTCH and the JITTER DISPLAY switch is set to ZERO.

2-39. The 0.5 Ampere slow-blow cartridge fuse may be replaced by unscrewing the fuseholder from the fuse post, and removing the fuse from the fuseholder.

2-40. The OUTPUT CONNECTOR has nine pins designated A through K, with the designations G and I omitted. The signals appearing at these pins are described below, and the output circuits, impedances and scale factors are discussed in Pars. 3-37 and 3-38. Note that the signals at Pins A and B are selected by the MODE switch.

A. Horizontal Deflection Voltage at the output of the Horizontal Pre-amplifier. This voltage, along with the Vertical Deflection Voltage at pin B, makes it possible to repeat the CRT display on a remote CRO.

B. Vertical Deflection Voltage at the output of the Vertical Preamplifier. This voltage, along with the Horizontal Deflection Voltage at pin A, makes it possible to repeat the CRT display on a remote CRO.

C. Normalized Notched Noise (NNN). This is the same signal that appears at the OUTPUT jacks on the front panel when the OUTPUT SELECT switch is in the position labeled NOTCHED NOISE RELATIVE TO OUTPUT LEVEL SETTING.

D. NNN cos wt. This is the same as that appearing on pin C, multiplied by cos wt, with no filtering. It is in phase with the steady-state input tone, and thus corresponds to amplitude jitter.

E. NNN sin wt. This is the same as that appearing on pin C, multiplied by sin wt, with no filtering. It is in quadrature with the steady-state input tone, and thus corresponds to phase jitter.

F. Normalized Input Signal. This is the signal at the output of the AGC Amplifier. This voltage remains approximately constant despite variations of the input signal, as long as those variations remain within the operating range of the AGC loop.

H. Input Level (AGC Control Voltage). This dc voltage varies logarithmically (and thus linearly in dB) with input signal level. This voltage has excellent short-term resolution, permitting readings of 0.1 dB in the presence of 20 dB of noise.

J. Sin wt. This is a 'scrubbed', noise-free version of the input tone, at reference level, and in quadrature with the input tone.

K. Circuit Ground. This is the same ground that is available at the ground banana jack on the front panel.

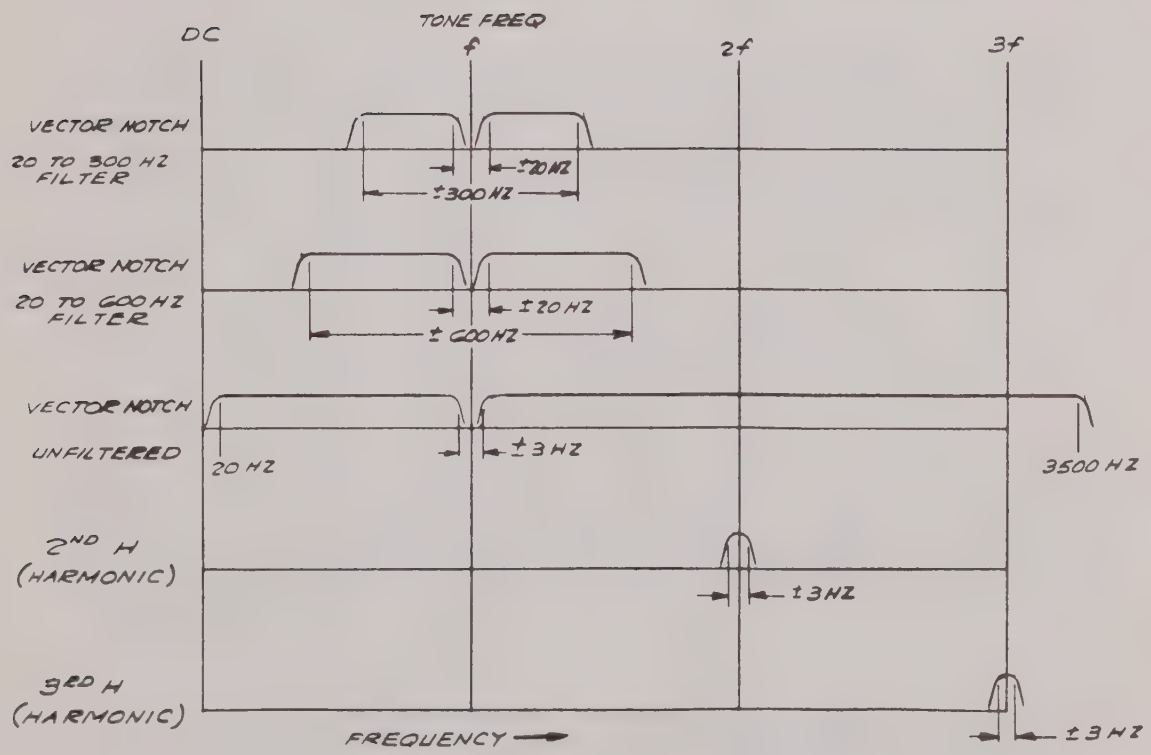

Figure 2-4 Bandwidth of PB-1 Display in Various Modes

THEORY OF OPERATION

3-1. GENERAL

3-2. SUPPRESSED-TONE PHASOR ANALYSIS METHOD

a. When a sinusoidal test tone is transmitted over a voiceband channel, the received signal contains a steady-state tone or quiet tone, plus tone-correlated disturbances (incidental AM, PM, and FM; harmonics; and hits, steps and dropouts) as well as non-correlated disturbances (SFI and noise).

b. Since the disturbances in the received signal are generally much smaller in magnitude than the test tone, it is difficult to measure those disturbances in the presence of that tone, which tends to obscure the disturbances. It is therefore desirable to remove the test tone (and only the test tone) from the received signal, so that the resulting 'notched noise' contains only the disturbances to be identified and measured.

c. It is also desirable to normalize the amplitude of the received signal so that the residual disturbances that constitute the notched noise can be measured against a calibrated scale.

d. The suppressed-tone phasor analysis method normalizes the received signal and eliminates the steady-state tone from the received signal; it then resolves the remaining disturbances into in-phase and quadrature components and displays them on a cathode-ray tube so that they can be separately identified and measured by means of calibrated scales on the CRT graticule.

e. The suppressed tone phasor analysis method employs two high-gain closed loops, an Automatic Gain Control (AGC) loop, and a Phase-Lock Loop (PLL), which are interconnected to operate as a narrowband notch filter that automatically tracks and suppresses the steady-state or quiet-tone component of a received signal.

f. The PLL tracks the frequency of the quiet tone and generates two orthogonal reference tones, one in phase with the quiet tone, and one in quadrature with the quiet tone.

g. The AGC loop tracks the level of the quiet tone and normalizes the received signal by amplifying the quiet tone to the same amplitude as that of the in-phase reference tone. Since the in-phase reference tone is of the same amplitude and phase as the quiet tone, it is equivalent to the quiet tone, and may be subtracted from the normalized received signal, leaving 'normalized notched noise' (i.e., normalized received signal minus quiet tone) containing only the normalized disturbances. This is equivalent to eliminating the quiet tone by means of an extremely narrow notch filter, but has the advantage that it automatically follows or tracks slow frequency variations of the quiet tone.

3-3. PB-1 SIMPLIFIED BLOCK DIAGRAM (Figure 3-1)

3-4. The simplified block diagram of Figure 3-1 shows how the suppressed-tone phasor analysis method is implemented by means of two interconnected loops, the Automatic Gain-Control (AGC) loop and the Phase-Lock Loop (PLL).

a. The received signal, comprising the quiet tone (V_r cos wt) and its accompanying disturbances, is fed to the AGC Amplifier, which amplifies the received signal to the level at which the quiet tone is equal to the in-phase reference tone (V_{ref} cos wt) from the PLL. The quiet tone and its disturbances, which are thus normalized in amplitude, are fed to the (+) input of the Difference Amplifier, as well as to the PLL.

b. The PLL locks to the quiet tone (V_r cos wt) in the normalized received signal and generates two synchronous reference tones; a reference tone (V_{ref} cos wt) in phase with the quiet tone, and a reference tone (V_{ref} sin wt) in quadrature with the quiet tone. The in-phase reference tone (V_{ref} cos wt) is fed to the (-) input of the Difference Amplifier and also to one input of the NNN Cos wt Multiplier; the quadrature reference tone (V_{ref} sin wt) is fed to one input of the NNN Sin wt Multiplier.

c. Since the (+) input to the Difference Amplifier is the normalized signal (V_r cos wt + disturbances), and the (-) input is the reference tone (V_{ref} cos wt), the output of the Difference Amplifier will be the normalized signal minus the quiet tone, or the normalized disturbances alone. Disturbances remaining after the quiet tone component of the received signal is removed, suppressed, or 'notched' from the signal, are conventionally called 'notched noise'. Since the PB-1 notches the quiet tone from the normalized received signal, the remaining disturbances are referred to as 'normalized notched noise', (NNN).

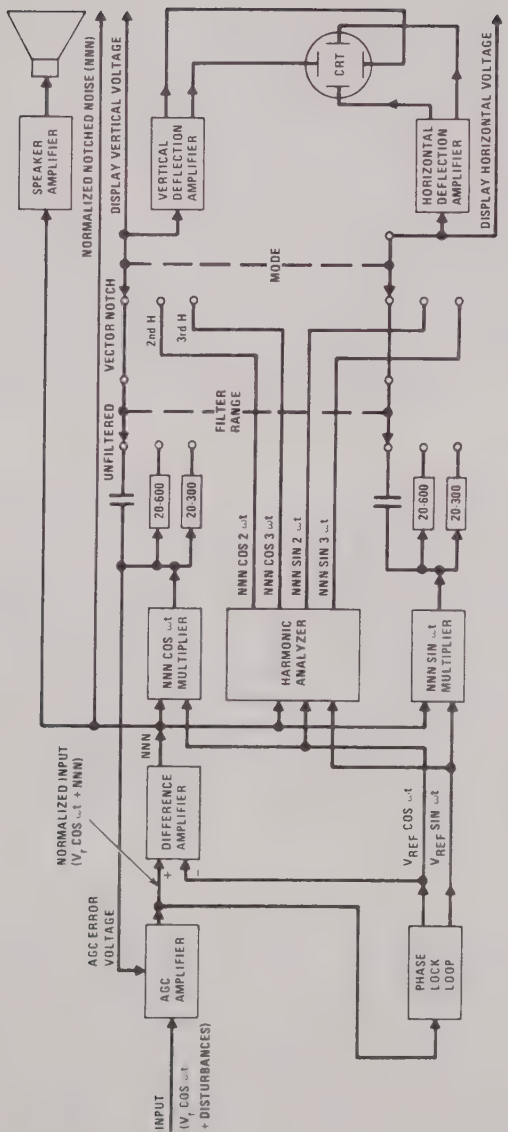

Figure 3-1 PB-1 Simplified Block Diagram

d. The NNN voltage from the Difference Amplifier is fed to one input of the NNN Cos wt Multiplier, where it is multiplied with the in-phase reference tone (V_{ref} cos wt) from the PLL to generate the NNN component in phase with the quiet tone. The NNN voltage is also fed to one input of the NNN Sin wt Multiplier, where it is multiplied with the quadrature reference tone (V_{ref} sin wt) from the PLL to generate the NNN component in quadrature with the quiet tone. The in-phase component (NNN cos wt) of the normalized notched noise is fed through a vertical deflection filter selected by the FILTER RANGE switch to the vertical deflection section of the MODE switch, and the quadrature component (NNN sin wt) of the normalized notched noise is fed through a horizontal deflection filter selected by the FILTER RANGE switch to the horizontal deflection section of the MODE switch. When the MODE switch is in the VECTOR NOTCH position, the NNN cos wt voltage is fed to the Vertical Deflection Amplifier that drives the vertical deflection plates of the cathode-ray tube (CRT), and the NNN sin wt voltage is fed to the Horizontal Deflection Amplifier that drives the horizontal deflection plates of the CRT. The FILTER RANGE switch, which is effective only in the VECTOR NOTCH position of the MODE switch, determines the bandwidth of the NNN components displayed on the CRT, by simultaneously selecting identical filters in both vertical and horizontal deflection channels. The filters selected may be either (20-300 Hz) or (20-600 Hz) bandpass filters or, in the UNFILTERED position, a high-pass coupling capacitor.

e. The in-phase component (NNN cos wt) of the normalized notched noise is also fed back as the AGC error voltage that controls the gain of the AGC amplifier. When the AGC Amplifier gain is such that the quiet tone component (V_r cos wt) of the AGC Amplifier output is exactly equal to the in-phase reference tone (V_{ref} cos wt) from the PLL, the quiet tone (V_r cos wt) is completely nulled by the in-phase reference tone (V_{ref} cos wt) at the input to the Difference Amplifier. The output of the Difference Amplifier then contains only normalized notched noise. Moreover, since this noise had been amplifier along with the steady-state tone component, the notched noise is <u>normalized</u> with respect to the in-phase reference tone, and may be measured by means of CRT graticule scales that are calibrated with respect to the in-phase reference tone.

f. The NNN voltage from the Difference Amplifier, and the in-phase and quadrature reference voltages (NNN cos wt and NNN sin wt) from the PLL are fed to a Harmonic Analyzer. This develops in-phase second and third harmonic components (NNN cos 2wt and NNN cos 3wt) and quadrature second and third harmonic components (NNN sin 2wt and NNN sin 3wt) of the normalized notched noise. In the 2ND H position of the MODE switch, the in-phase second harmonic component (NNN cos 2wt) is fed to the Vertical Deflection Amplifier, and the quadrature second harmonic component (NNN sin 2wt) is fed to the Horizontal Deflection Amplifier.

Similarly, in the 3RD H position of the MODE switch, the in-phase third harmonic component (NNN cos 3wt) is fed to the Vertical Deflection Amplifier, and the quadrature third harmonic component (NNN sin 3wt) is fed to the Horizontal Deflection Amplifier. Since the components displayed in the 2ND H and 3RD H position of the MODE switch are derived from the normalized notched noise, they may also be measured against the CRT calibrated graticule scales.

g. The quantities NNN, NNN sin wt, and NNN cos wt, are brought out to connector pins at the rear of the PB-1 for remote recording and/or display. In addition, the quantity NNN is fed through an amplifier to a loudspeaker, and through the OUTPUT SELECT switch to the panel OUTPUT jacks.

h. The time constants of the AGC loop and of the Phase-Lock Loop are adjusted so that both loops operate rapidly enough to recover from transients within the 1/7 second dead-zone interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients.

3-5. PB-1 DETAILED BLOCK DIAGRAM (Figure 3-2)

3-6. AUTOMATIC GAIN CONTROL (AGC) LOOP

3-7. The AGC Loop comprises an AGC Preamplifier, AGC Amplifier, AGC DC Amplifier, Difference Amplifier, NNN Cos wt Multiplier, NNN cos wt DC Amplifier, and an AGC Error Voltage Integrator.

3-8. The received signal is fed to the AGC Preamplifier through an input transformer that reflects an input impedance determined by the setting of an input termination switch. In the BRIDGE position of the input termination switch, the secondary of the input transformer is loaded only by the input impedance of the AGC Preamplifier, so that the primary impedance of the input transformer is nominally 30,000 ohms. In the 900Ω and 600Ω positions, corresponding resistors are connected across the input of the AGC Preamplifier, and thus across the secondary of the input transformer, causing the primary input impedance to be 900 ohms and 600 ohms respectively.

3-9. The LEVEL ADJ switch varies the gain of the AGC Preamplifier in discrete 5 dB steps by inserting fixed resistors in the AGC Preamplifier feedback loop. The resistance values inserted in the various LEVEL ADJ switch positions are such that, in the dBm LEVEL position of the MODE switch, the vertical deflections will be zero when the input signal is -30, -25, -20, -15, -10, -5, 0, and +5 dBm. The LEVEL ADJ switch thus

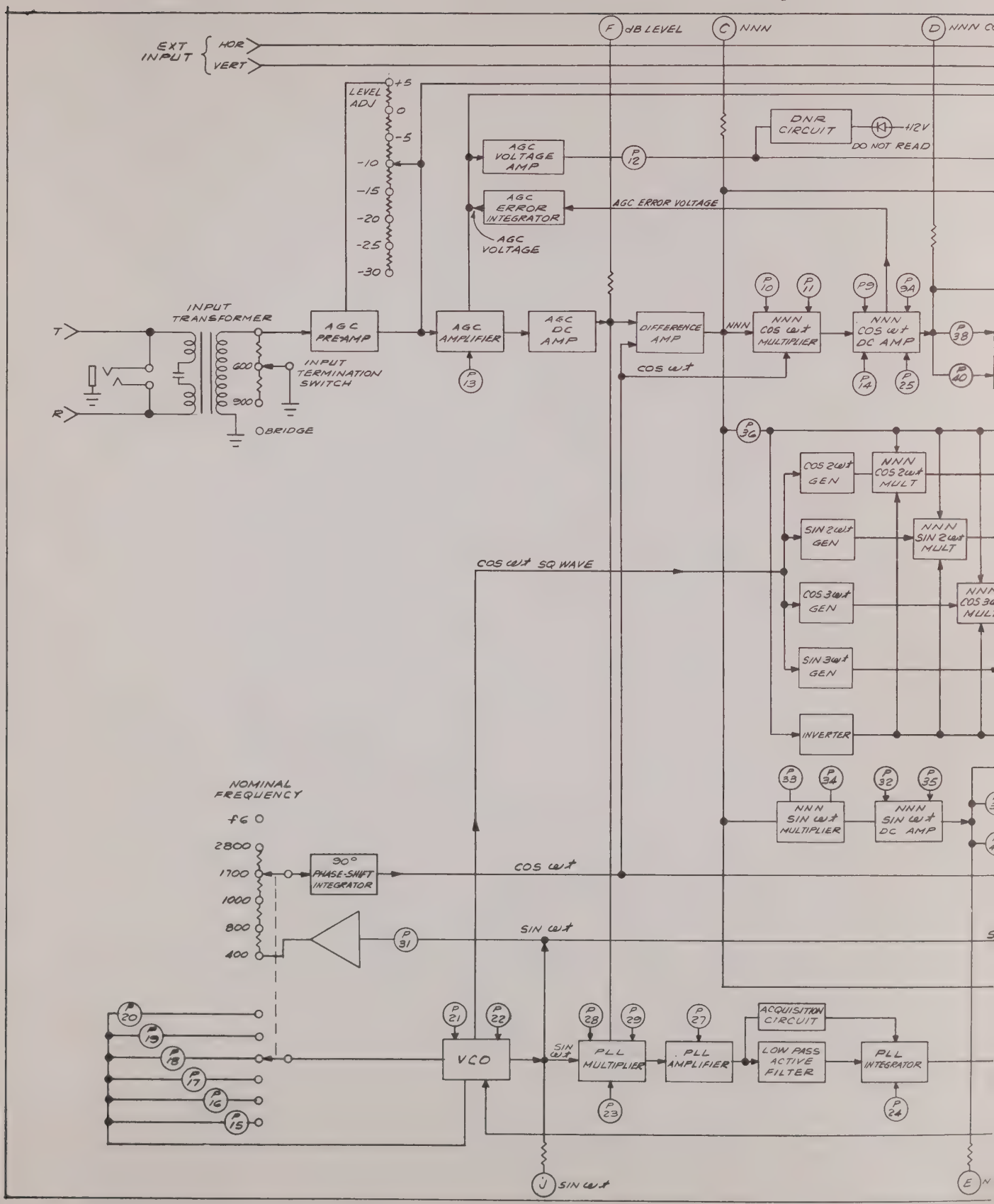

Figure 3-2 PB-1 Detailed Block Diagram

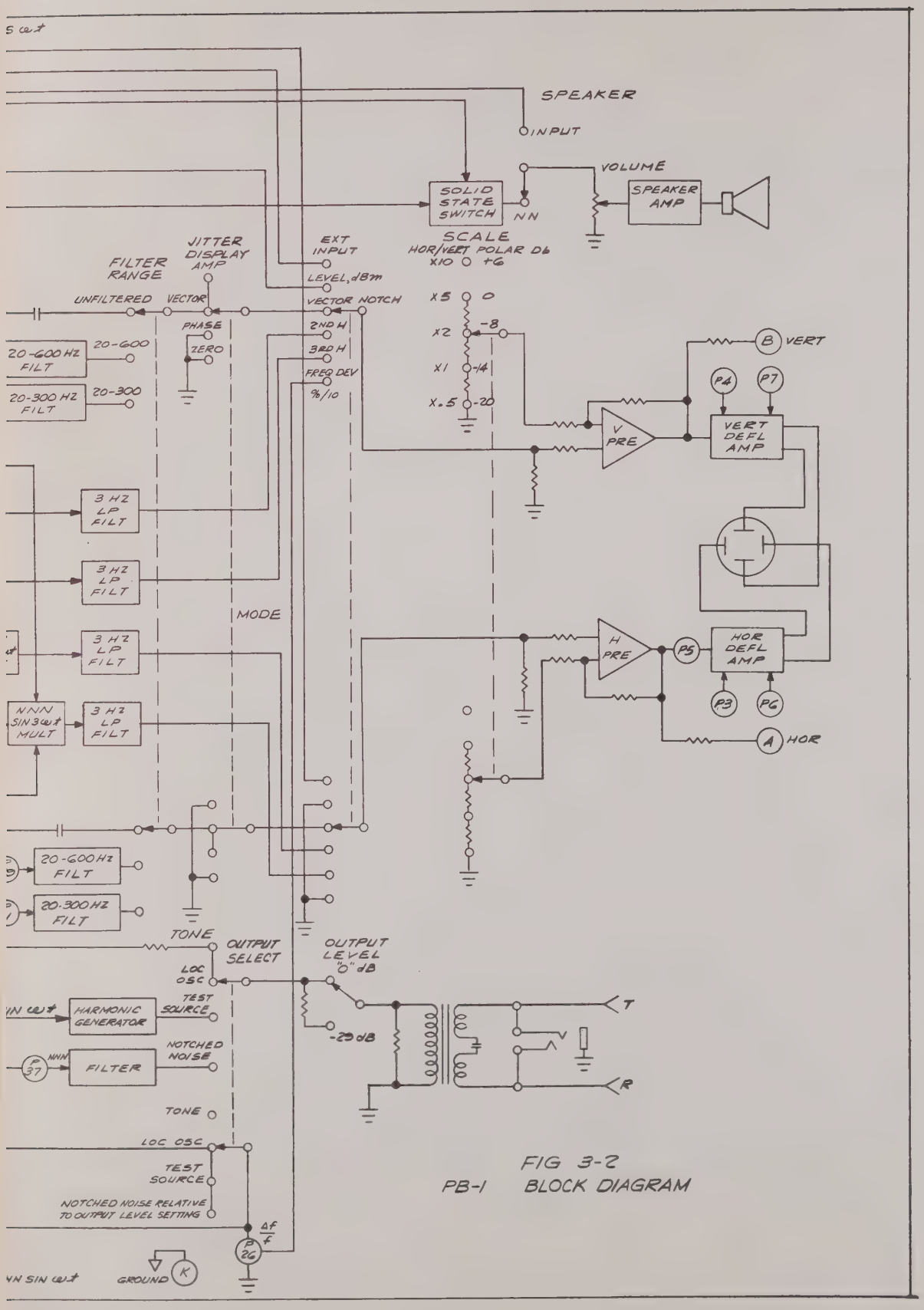

FIG 3-2
PB-1 BLOCK DIAGRAM

permits the operator to offset the input tone level in 5 dB steps from -30 to +5 dBm. The level-adjusted output of the AGC Preamplifier is fed to the AGC Amplifier.

3-10. The gain of the AGC Amplifier is controlled by the AGC Voltage from the AGC Error Voltage Integrator. The output of the AGC Amplifier, which is the quiet tone (V_r cos wt) plus disturbances, is fed through the AGC DC Amplifier to the (+) input of the Difference Amplifier; and the in-phase reference tone (V_{ref} cos wt) from the Phase-Lock Loop is fed to the (-) input of the Difference Amplifier. The output of the Difference Amplifier is therefore

$$(V_r \cos wt + \text{disturbances}) - V_{ref} \cos wt,$$

which may be written

$$(V_r \cos wt - V_{ref} \cos wt) + \text{disturbances},$$

or $$(V_r - V_{ref}) \cos wt + \text{disturbances}$$

a. If the quiet tone (V_r cos wt) is not equal to the in-phase reference tone (V_{ref} cos wt), the output of the Difference Amplifier will contain the residual tone ($V_r - V_{ref}$) cos wt plus the disturbances.

b. If the quiet tone is equal to the in-phase reference tone, the residual tone becomes zero, and the Difference Amplifier output contains only the disturbances. Since the entire received signal has been normalized in the process of amplifying the quiet tone (V_r cos wt) to exactly the same level as the in-phase reference tone (V_{ref} cos wt), the disturbances or notched noise remaining after the quiet tone has been removed, may be called Normalized Notched Noise (NNN).

3-11. The output of the Difference Amplifier is fed to one input of the NNN Cos wt Multiplier, and the in-phase reference tone (V_{ref} cos wt) from the PLL is fed to the other input. The output of the NNN Cos wt Multiplier depends on whether the residual tone ($V_r - V_{ref}$) cos wt is equal to zero.

a. If the residual tone, ($V_r - V_{ref}$) cos wt is equal to zero, the output of the NNN Cos wt Multiplier is the in-phase component of Normalized Notched Noise, or NNN cos wt.

b. If the residual tone ($V_r - V_{ref}$) cos wt is not equal to zero, the output of the Multiplier will contain, in addition to the NNN Cos wt voltage, a $(\cos wt)^2$ term. From the trigonometric identity,

$$(\cos wt)^2 = \tfrac{1}{2} + \tfrac{1}{2}(\cos 2\,wt),$$

it can be seen that the $(\cos wt)^2$ term comprises a DC average component and an AC component at twice the frequency of the quiet tone.

3-12. The output of the NNN Cos wt Multiplier is fed to the NNN Cos wt DC Amplifier. One output of the NNN Cos wt DC Amplifier is fed to the vertical FILTER RANGE circuits, and a second output (the AGC Error Voltage) is fed to the AGC Error-Voltage Integrator. The AGC Error-Voltage Integrator filters out all AC components and integrates the DC component. The integrated DC output of the AGC Error-Voltage Integrator is used as the AGC Voltage, which varies the gain of the AGC Amplifier until the DC component in the output of the NNN Cos wt Multiplier becomes zero. This occurs when the quiet tone (V_r cos wt) in the AGC Amplifier output is exactly equal in amplitude to the in-phase reference tone (V_{ref} cos wt) from the PLL, so that the residual tone ($V_r - V_{ref}$) cos wt becomes zero. In this condition, there is no $(\cos wt)^2$ component in the output of the NNN Cos wt Multiplier, which thus contains only the in-phase component (NNN cos wt) of Normalized Notched Noise.

3-13. The AGC Voltage is also fed through the AGC Voltage Amplifier to the dBm LEVEL position of the MODE switch, so that it may be displayed as a vertical deflection on the CRT. Since the AGC Voltage is proportional to the logarithm of the amplitude (V_r) of the received tone, the vertical scale on the CRT graticule is calibrated directly in dB. The dBm level of the input signal is then equal to the algebraic sum of the value of the dBm LEVEL switch position and the vertical spot deflection as measured against the vertical dB scale. (Note that the vertical spot deflection must be multiplied by the factor indicated by the setting of the SCALE switch, before adding the level indicated by the dBm LEVEL switch setting).

3-14. PHASE-LOCK LOOP (PLL)

3-15. The Phase-Lock Loop comprises a Voltage-Controlled Oscillator (VCO), PLL Multiplier, PLL Amplifier, Low-Pass Active Filter, Acquisition Circuit, PLL Integrator, and a 90° Phase-Shift Integrator.

3-16. The VCO operates within any one of six frequency ranges determined by the position of the NOMINAL FREQUENCY switch, and in one of two modes (free-running or tracking) determined by the OUTPUT SELECT switch, one section of which opens or closes the Phase-Lock Loop.

a. In the TONE position of the OUTPUT SELECT switch, the Phase-Lock Loop is open, and the VCO is free-running at the center frequency determined by the setting of one of six adjustment potentiometers (P15 through P20) selected by the NOMINAL FREQUENCY switch. Potentiometers P15 through P19 are set so that when the OUTPUT SELECT switch is at TONE, and the NOMINAL FREQUENCY switch is set to the positions labeled 400, 800, 1000, 1700, or 2800 Hz, the actual free-running center frequency of the VCO will be 404, 804, 1004, 1704, or 2804 Hz. A sixth position of the NOMINAL FREQUENCY switch selects optional potentiometer P20, which trims the optional free-running center frequency of the VCO.

b. In any one of the other three positions (LOC OSC, TEST SOURCE, or NOTCHED NOISE) of the OUTPUT SELECT switch, the VCO operates within the closed Phase-Lock Loop.

c. The VCO directly generates the quadrature sinusoidal reference tone (V_{ref} sin wt), an in-phase square wave, and a pulse at the rising transition of the in-phase square wave.

d. The quadrature reference tone (V_{ref} sin wt) from the VCO is fed through a Phase-Shift-Integrator Driver Amplifier to the 90° Phase-Shift Integrator, which develops the in-phase reference tone (V_{ref} cos wt). Since the gain of an integrator varies inversely with frequency, the input resistance of the 90° Phase-Shift Integrator is determined by one section of the NOMINAL FREQUENCY switch, which decreases the input resistance at higher frequencies, so that the gain of the 90° Phase-Shift Integrator is exactly compensated at each center frequency, and the in-phase reference tone (V_{ref} cos wt) is thus the same amplitude at each center frequency (404, 804, 1004, 1704, and 2804 Hz).

e. Since the in-phase reference tone (V_{ref} cos wt) is developed by integration of the quadrature reference tone (V_{ref} sin wt), the in-phase reference tone is extremely pure, and thus is equivalent to the steady-state received tone with all disturbances 'scrubbed' from it.

3-17. The quadrature reference tone (V_{ref} sin wt) from the VCO is fed to one input of the PLL Multiplier, and the normalized input signal from the AGC DC Amplifier is fed to the other input of the PLL Multiplier. Since the steady-state tone component of the normalized signal is V_r cos wt, and the quadrature reference tone is V_{ref} sin wt, the PLL Multiplier output would ideally be zero if the two tones were exactly orthogonal, even if the amplitudes V_r and V_{ref} were not equal. However, if the quadrature reference tone (V_{ref} sin wt) is not exactly orthogonal to the steady-state received tone, the PLL Multiplier output will contain some double-frequency components and a DC component that is approximately proportional to the phase error between V_{ref} sin wt and V_r cos wt.

3-18. The PLL Multiplier output is fed through the PLL Amplifier and Low-Pass Active Filter to the PLL Integrator, which filters out the double-frequency components and averages the DC component. The magnitude of the DC output from the PLL Integrator is approximately proportional to the relative frequency difference:

$$\frac{f_{input} - f_{VCO}}{f_{VCO}} = \frac{\Delta f}{f}$$

This integrated DC signal is fed (through the OUTPUT SELECT switch, in the LOC OSC, TEST SOURCE or NOTCHED NOISE positions) back to the VCO as the frequency control voltage that causes the VCO reference tone output (V_{ref} sin wt) to be precisely in quadrature with the steady-state received tone. The VCO is thus phase-locked to the steady-state tone component of the received signal, and will track that steady-state tone over a ± 8% range from the center frequency (404, 804, 1004, 1704, or 2804 Hz., and f6) selected by the NOMINAL FREQUENCY switch.

3-19. Since the DC output of the PLL Integrator is approximately proportional to the relative frequency difference, $\Delta f/f$, it is approximately proportional to the percent deviation of the steady-state received tone from the nominal frequency. This $\Delta f/f$ DC voltage can (in the FREQ DEV, %/10 position of the MODE switch) be fed to the Vertical Amplifiers so that the deflection may be measured against a vertical scale calibrated in percent frequency deviation. A fixed frequency shift will be displayed as a proportional fixed vertical deflection; and the slow frequency variation caused by low-frequency jitter will be displayed as a cyclical vertical deflection, with the deflection frequency and amplitude corresponding to the jitter frequency and phase-shift magnitude.

3-20. When the PLL is locked to and is tracking an input signal, the PLL bandwidth is approximately ± 0.25%. When the input signal frequency and the VCO frequency differ by more than the ± 0.25% bandwidth of the PLL, a beat-frequency voltage will exist at the outputs of the PLL Multiplier and the PLL Amplifier. This beat-frequency voltage will be large because the AGC loop operates at maximum gain when the PLL is not locked to an input signal. (The DO NOT READ lamp will therefore go on). The beat-frequency voltage will be detected by the Acquisition Circuit, which will then increase the PLL bandwidth from the ± 0.25% tracking bandwidth to the ± 8% acquisition bandwidth. If this greatly increased bandwidth is still not sufficient to cause the PLL to acquire the input signal (e.g., if the PLL frequency is 8% low, and the input signal is 8% high), the Acquisition Circuit will then generate pulses that cause the PLL frequency to move toward the center frequency indicated by the NOMINAL FREQUENCY switch. At this center frequency, the PLL can acquire any input signal that is within ± 8% of the nominal center frequency. When the PLL acquires the input signal, the PLL frequency will shift towards the input frequency. When the PLL frequency shifts to within ± 0.25% of the input frequency, the Acquisition Circuit will switch the PLL once again to its ± 0.25% tracking bandwidth, the AGC loop will operate normally, and the DO NOT READ lamp will go off.

3-21. The quadrature reference tone (V_{ref} sin wt) from the VCO is fed to one input of the NNN Sin wt Multiplier, and the normalized notched noise from the Difference Amplifier is fed to the other input of the same Multiplier. The output (NNN Sin wt) of the Multiplier is the quadrature component of the normalized notched noise. This is fed through the NNN Sin wt DC Amplifier to the Horizontal FILTER RANGE circuits.

3-22. HARMONIC DISTORTION MEASUREMENT CIRCUITS

3-23. The in-phase square wave from the VCO is fed to four frequency multipliers that generate in-phase and quadrature gate or reference voltages (cos 2wt and sin 2wt) at twice the frequency of the received tone, and in-phase and quadrature reference voltages (cos 3wt and sin 3wt) at three times the frequency of the received tone. Each of the four reference voltages is fed to the reference input of a separate harmonic analyzer multiplier; the normalized notched noise and (through an inverter) the negative of the normalized notched noise are fed to the signal inputs of the same four harmonic analyzer multipliers. The outputs NNN cos 2wt and NNN sin 2wt are the in-phase and quadrature components of the second-harmonic content of the notched noise; and the outputs NNN cos 3wt and NNN sin 3wt are the in-phase and quadrature components of the third-harmonic content of the notched noise. These four outputs are fed through 3-Hz low-pass filters to appropriate contacts on the MODE switch for display on the CRT when that switch is in the 2ND H or the 3RD H positions.

3-24. DISPLAY CIRCUITS

3-25. The FILTER RANGE, JITTER DISPLAY, MODE, and SCALE switches are all associated with the PB-1 Cathode-Ray Tube display. The MODE switch permits selection of the various display modes, and the SCALE switch determines the CRT horizontal and vertical deflection sensitivities in each mode. The FILTER RANGE and JITTER DISPLAY switches are effective only in the VECTOR NOTCH position of the MODE switch, to permit detailed analysis of the normalized notched noise being displayed in the VECTOR NOTCH mode. Each of the four switches has a section for the CRT vertical deflection channel, and a section for the CRT horizontal deflection channel. The 'horizontal' and 'vertical' sections of each switch are simultaneously actuated by its control knob.

3-26. The FILTER RANGE Switch determines the bandwidth of the NNN components displayed in the VECTOR NOTCH position of the MODE switch. The in-phase component (NNN Cos wt) of the normalized notched noise is fed through one of three bandwidth-determining circuits to the vertical section of the FILTER RANGE switch, and the quadrature component (NNN sin wt) of the normalized notched noise is fed through one of three bandwidth-determining circuits to the horizontal section of the same switch.

The output from the arm of the vertical section of the FILTER RANGE switch is fed to the vertical section of the JITTER DISPLAY switch, and the output from the arm of the horizontal section of the FILTER RANGE switch is fed to the horizontal section of the JITTER DISPLAY switch.

a. In the UNFILTERED position of the FILTER RANGE switch, the vertical and horizontal outputs of the switch are NNN cos wt and NNN sin wt, respectively, with the DC components removed by blocking capacitors.

b. In the (20-600) Hz position, the vertical and horizontal outputs of the switch are NNN cos wt and NNN sin wt respectively, with bandwidths limited by (20-600) Hz filters.

c. In the (20-300) Hz position, the vertical and horizontal outputs of the switch are NNN Cos wt and NNN Sin wt respectively, with bandwidths limited by (20-300) Hz filters.

3-27. The JITTER DISPLAY Switch determines whether the in-phase or the quadrature component of normalized notched noise is displayed, or both components, or neither component.

a. In the AMPLITUDE position, the in-phase component (NNN cos wt) of the normalized notched noise is fed to the VECTOR NOTCH contact on the vertical section of the MODE switch; and the VECTOR NOTCH contact on the horizontal section of the MODE switch is grounded.

b. In the VECTOR position of the JITTER DISPLAY switch, NNN cos wt is fed to the VECTOR NOTCH contact on the vertical section of the MODE switch, and NNN sin wt is fed to the VECTOR NOTCH contact on the horizontal section of the MODE switch.

c. In the PHASE position of the JITTER DISPLAY switch, the VECTOR NOTCH contact on the vertical section of the MODE switch is grounded, and the quadrature component (NNN sin wt) of the normalized notched noise is fed to the VECTOR NOTCH contact on the horizontal section of the MODE switch.

d. In the ZERO position of the JITTER DISPLAY switch, both arms of the switch are grounded, so that no signals are fed to the MODE switch.

3-28. The MODE Switch selects the various voltages to be displayed on the CRT. The voltages (NNN cos wt, NNN sin wt, NNN cos 2 wt, NNN sin 2 wt, NNN cos 3 wt, NNN sin 3 wt, AGC voltage, and $\Delta f/f$ voltage) that have been derived from the received signal, as well as any voltages that are fed to the HOR and VERT EXT INPUTS, may be selected by means of the MODE switch for display on the CRT. The selected voltage at the arm of the vertical section of the MODE switch is fed through the Vertical Preamplifier and the Vertical Deflection Amplifier to the CRT vertical deflection plates, and the selected voltage at the arm of the horizontal section of the MODE switch is fed through the Horizontal Preamplifier and the Horizontal Deflection Amplifier to the CRT horizontal deflection plates.

a. In the EXT INPUT position, signals fed to the HOR and VERT EXT INPUTS jacks on the PB-1 panel, are fed to the corresponding amplifiers. In this mode, the PB-1 is a vectorscope.

b. In the LEVEL, dBm position, the logarithmic AGC voltage is fed to the vertical amplifier, and the input to the horizontal amplifier is grounded. The display is then a vertical deflection, which is measured against the calibrated vertical dB scale on the graticule.

c. In the VECTOR NOTCH position, the in-phase component (NNN cos wt) of normalized notched noise is fed through the vertical sections of the FILTER RANGE, JITTER DISPLAY, and MODE switches, to the CRT vertical amplifiers, and the quadrature component (NNN sin wt) of normalized notched noise is fed through the horizontal sections of the FILTER RANGE, JITTER DISPLAY, and MODE switches, to the CRT horizontal amplifiers. As explained in Par. 3-26, the FILTER RANGE switch determines the bandwidth (UNFILTERED, 20-600 Hz, or 20-300 Hz) of the voltages being displayed. As explained in Par. 3-27, the JITTER DISPLAY switch determines whether the in-phase or the quadrature component of normalized notched noise is fed to the MODE switch for display. In the AMPLITUDE position of the JITTER DISPLAY switch, the arm of the horizontal section of the MODE switch is grounded, so that only the in-phase component (NNN cos wt) of the normalized notched noise is displayed (i.e., there is only a vertical deflection). In the VECTOR position, both the in-phase component (NNN cos wt) and the quadrature component (NNN sin wt) of normalized notched noise are displayed,(i.e., there are both horizontal and vertical deflections). In the PHASE position, the arm of the vertical section of the MODE switch is grounded, so that only the quadrature component (NNN sin wt) of normalized notched noise is displayed (i.e., there is only a horizontal deflection). In the ZERO position, the arms of both the vertical and horizontal sections of the MODE switch are grounded, so that there can be neither vertical nor horizontal deflection. In this condition, the HOR and VERT ZEROING adjustments at the rear of the PB-1 may be used to zero the spot deflection.

d. In the 2ND H position of the MODE switch, the in-phase component (NNN cos 2 wt) and quadrature component (NNN sin 2 wt) of the second-harmonic content of the normalized notched noise are fed to the vertical and horizontal amplifiers, respectively.

e. In the 3RD H position of the MODE switch, the in-phase component (NNN cos 3 wt) and quadrature component (NNN sin 3 wt) of the third-harmonic content of the normalized notched noise are fed to the vertical and horizontal amplifiers, respectively.

f. In the FREQ DEV (%/10) position of the MODE switch, the arm of the vertical section of the MODE switch feeds the $\Delta f/f$ voltage (from the Phase-Lock Loop) to the CRT vertical amplifier, and the arm of the horizontal section of the MODE switch grounds the input of the CRT Horizontal Amplifier. There is thus only a vertical deflection, which is proportional to the percent deviation of the input tone from the specified center frequency (404, 804, 1004, 1704, or 2804 Hz, or f6). If the SCALE switch is in the X10 position, the percent frequency deviation ($100\ \Delta f/f$) can be read directly on the vertical percent scale of the CRT graticule.

3-29. The SCALE Switch determines the deflection sensitivity of the CRT. The vertical section of the SCALE switch controls the gain of the Vertical Preamplifier, and the horizontal section controls the gain of the Horizontal Preamplifier. Since these two sections are ganged, they simultaneously vary the CRT vertical and horizontal deflection sensitivities.

3-30. SPEAKER CIRCUITS

3-31. The normalized notched noise from the Difference Amplifier is fed through a solid-state switch to the NOTCH contact of the SPEAKER toggle switch. The output of the AGC Preamplifier is fed to the INPUT contact of the SPEAKER switch. The arm of the SPEAKER switch is connected to the VOLUME control potentiometer that feeds the Speaker Amplifier. The solid-state switch is normally closed, so that, when the SPEAKER switch is set to NOTCH, the normalized notched noise is fed through the VOLUME control and Speaker Amplifier to the speaker. However, any sudden large increase in the normalized notched noise voltage, which will result in a corresponding increase in volume, also will cause an increase in the AGC voltage; and this increased AGC voltage will open the solid-state switch, and disconnect the NNN signal from the SPEAKER switch until the AGC loop functions to reduce the NNN to the normalized level.

3-32. ELECTRICAL OUTPUTS

3-33. Panel Electrical Outputs

3-34. The OUTPUT SELECT switch has two sections, one of which determines the voltage to be fed to the OUTPUT LEVEL switch, and the second of which determines whether the Phase-Lock Loop is closed (acquisition/tracking operation) or open (free-running VCO).

a. In the TONE position, the arm of the OUTPUT SELECT switch is connected to the voltage (V_{ref} cos wt) from the 90° Phase-Shift Integrator, and the PLL is opened, so that the VCO is free-running at the center frequency (404, 804, 1004, 1704, or 2804 Hz or f6) selected by the NOMINAL FREQUENCY switch.

b. In the LOC OSC position, the arm of the OUTPUT SELECT switch is connected to the same voltage (V_{ref} cos wt) from the 90° Phase-Shift Integrator as in the TONE position; but the PLL is closed, so that the VCO tracks the steady-state received tone, and the LOC OSC output (V_{ref} cos wt) is thus equivalent to the steady-state received tone (V_r cos wt) scrubbed clean of all disturbances. The LOC OSC output can therefore be retransmitted, used to synchronize an external oscilloscope for time-domain display of the received tone, or fed to an external frequency counter.

c. In the TEST SOURCE position, the arm of the OUTPUT SELECT switch is connected through a Harmonic Generator to the (V_{ref} sin wt) output of the VCO, and the PLL is closed so that the VCO tracks the steady-state received tone. The output is thus rich in harmonics of the steady-state received tone.

d. In the NOTCHED NOISE RELATIVE TO OUTPUT LEVEL SETTING position, normalized notched noise from the output of the Difference Amplifier is fed through a 3000 Hz low-pass filter to the arm of the OUTPUT SELECT switch. The output level of this NNN output is, as stated by the panel marking, relative to the 0 dBm or the -29 dBm setting of the OUTPUT LEVEL toggle switch.

3-35. The voltage selected by the OUTPUT SELECT switch is fed through the OUTPUT LEVEL toggle switch to the output transformer.

a. In the 0(dBm) setting, the full voltage from the OUTPUT SELECT switch is fed to the output transformer.

b. In the -29(dBm) setting, the voltage fed to the output transformer from the OUTPUT SELECT switch is attenuated by 29 dB with respect to the voltage in the 0(dBm) position.

3-36. The secondary of the output transformer is connected to the panel OUTPUT jacks. It presents a 600-ohm balanced source impedance to any load connected across those OUTPUT jacks. Note that the 0 dBm and -29 dBm levels selected by the OUTPUT LEVEL switch are correct only when the load is 600 ohms. The actual levels must be corrected for loads other than 600 ohms.

3-37. Rear Connector Outputs

3-38. As shown in the detailed block diagram (Figure 3-2), various signals are brought to pins of a nine-pin connector at the rear of the PB-1 for connection to external instruments such as cathode-ray oscilloscopes, recorders, noise meters, impulse counters, etc. The pin designations and outputs are listed below. Note that pin designations G and I are omitted.

3-39. The signals at Pins A and B are selected by the MODE switch, and the voltage levels of these signals are thus proportional to the CRT deflections in the selected display modes. The signals on Pins A and B, at the various MODE switch settings, are summarized in the table below.

MODE	Pin A Signal	Pin B Signal
EXT INPUT	EXT HOR Input	EXT VERT Input
LEVEL, dBm	No Output	Quiet-Tone Level
VECTOR NOTCH	NNN sin wt	NNN cos wt
2ND H	NNN sin (2wt)	NNN cos (2wt)
3RD H	NNN sin (3wt)	NNN cos (3wt)
FREQ DEV, %/10	No Output	$\Delta f/f$

3-40. The Pin A signal is the Horizontal Deflection Voltage at the output of the Horizontal Preamplifier. This voltage is dc-coupled to Pin A through a 1 kilohm resistor. There is no dc offset as long as the CRT spot is horizontally centered.

a. As stated in Par. 3-39, the signal appearing at Pin A is selected by the MODE switch. In the EXT INPUT, VECTOR NOTCH, 2ND H, and 3RD H modes, the Pin A voltage (into a load impedance of 10 kilohms or more) for full-scale left-hand and right-hand deflections (i.e., to the -10 dB polar circle) is approximately +4.5 V and -4.5 V respectively.

b. The Pin A voltage is always zero in the dBm LEVEL and FREQ DEV modes, because there is no horizontal deflection in either of these modes.

3-41. The Pin B signal is the Vertical Deflection Voltage at the output of the Vertical Preamplifier. This signal is dc-coupled to Pin B through a 1 kilohm resistor. There is no dc offset as long as the CRT spot is vertically centered.

a. As stated in Par. 3-39, the voltage appearing at Pin B is selected by the MODE switch. In all modes, the Pin B voltage (into a load impedance of 10 kilohms or more) for full-scale upward and downward deflections, (i.e., to the -10 dB polar circle) is approximately -4.5 V and +4.5 V respectively.

b. In the dBm LEVEL mode, the Pin B output is a dc voltage proportional to the CRT vertical deflection, and thus is proportional to the dB deviation of the input quiet-tone level from the level indicated by the LEVEL ADJ switch. In the dBm LEVEL mode, full-scale upward and downward deflections (i.e., to the -10 dB circle) correspond to Pin B outputs of approximately -4.5 or +4.5 VDC respectively. Note that, in the dBm LEVEL mode, if the PB-1 input impedance does not match the line impedance, the mismatch will appear as zero offsets in both the CRT vertical deflection and the Pin B output voltage.

c. In the FREQ DEV mode, the Pin B output is a dc voltage proportional to the percent frequency deviation of the input frequency from the specified frequency (i.e., 404, 804, 1004, 1704, 2804, and f6 Hz), and full-scale upward or downward deflections (i.e., to the -10 dB circle) correspond to voltages of approximately -4.5 or +4.5 VDC respectively.

3-42. The Pin C signal is Normalized Notched Noise (NNN). This is the same signal that appears at the front panel OUTPUT jacks when the OUTPUT SELECT switch is in the position labeled NOTCHED NOISE RELATIVE TO OUTPUT LEVEL SETTING. When the OUTPUT jacks are loaded with 600 ohms, and Pin C is loaded with 10 kilohms or more, the voltage at Pin C is approximately 16 dB or 6 times greater than the signal at the OUTPUT jacks. The signal is dc-coupled to Pin C through a 1 kilohm resistor. This output is unfiltered, and contains all notched noise components from power-line frequencies to 4000 Hz.

3-43. The Pin D signal is the NNN Sin wt Voltage. This is the quadrature or phase jitter component of the Normalized Notched Noise on Pin C, and is proportional to the horizontal deflection in the VECTOR NOTCH mode. This voltage is unfiltered, and contains all notched noise components from power-line frequencies to 4000 Hz. The signal is dc-coupled to Pin D through a 1 kilohm resistor, and there may be a dc offset as large as ±2 VDC. When Pin D is loaded with 10 kilohms or more, full-scale deflections to the left or right (i.e., to the -10 dB circle) correspond to voltages of approximately +4.5 V or -4.5 V respectively.

3-44. The Pin E signal is the NNN Cos wt Voltage. This is the in-phase component of the Normalized Notched Noise on Pin C, and is proportional to the vertical deflection in the VECTOR NOTCH mode. This voltage is unfiltered, and contains all notched noise components from power-line frequencies to 4000 Hz. The signal is dc-coupled to Pin E through a 1 kilohm resistor. When Pin E is loaded with 10 kilohms or more, full-scale upward or downward deflections (i.e., to the -10 dB circle) correspond to voltages of approximately -4.5 V or +4.5 V respectively.

3-45. The Pin F signal is the Normalized Input Signal (comprising quiet tone plus disturbances) at the output of the AGC Amplifier. The level of the quiet-tone in this signal remains approximately constant despite input-level variations, as long as those variations remain within the operating range of the AGC loop. The Pin F voltage is approximately 3.5 V p-p when the quiet tone is at any specified center frequency, and varies inversely with variations of the input quiet tone from that center frequency.

3-46. The Pin H signal is the Input Quiet-Tone Level (AGC Control Voltage). This dc voltage varies logarithmically (and thus linearly in dB) with variations in quiet-tone from the level indicated by the LEVEL ADJ setting. The scale factor is approximately -0.4 VDC for a +1 dB change (and +0.4 VDC for a -1 dB change). The output impedance is between 1 and 2 kilohms.

3-47. The Pin J signal is Sin wt, from the Voltage-Controlled Oscillator of the PLL. This is a 'scrubbed', noise-free version of the input tone, at reference level, and in quadrature with the input tone. The voltage at Pin J is approximately 12 V p-p, and is independent of input quiet-tone frequency variations over a ±8% range.

3-48. Pin K is connected to the circuit ground. This is the same ground that is available at the ground banana jack on the front panel.

OPERATION AND DATA INTERPRETATION

4-1. INTRODUCTION

a. Appendix A of this manual describes a procedure for familiarization with the PB-1 VF Line Analyzer by operation with the Bradley Telcom 2A/2B Line Simulator. This is an extremely powerful procedure; it not only develops skill in operation of the PB-1 but acquaints the operator with the appearance of all types of line disturbances, singly and in combinations. Because the familiarization procedure is so useful, Bradley Telcom will rent 2A/2B Simulators at nominal charge to owners of PB-1 Analyzers.

b. A Facility Evaluation Report Form is included at the end of this section. This form represents a procedure for analyses of any voice-frequency facility by means of the PB-1, as well as a convenient method of recording the data thus obtained.

c. PB-1 displays may be recorded photographically. The PB-1 settings for each photograph should be carefully recorded, so that the photographed displays may be quantified at any subsequent time. If Polaroid photographs are made, as in Pars. 4-11 through 4-13, the PB-1 settings may be recorded on the back of each print.

d. A wide range of electrical outputs is available at front-panel output jacks and at a nine-pin rear connector. These electrical outputs may be recorded on external strip-chart recorders or tape recorders.

4-2. OPERATION

4-3. START-UP PROCEDURE

a. Connect power cable to 115 VAC, 60 Hz, single-phase power source.

b. Set power switch to ON.

c. Check CRT zero deflection position by setting MODE switch to VECTOR NOTCH, SCALE switch to X0.5, and JITTER DISPLAY switch to ZERO. If CRT deflection is not at zero, wait 10 minutes for full warmup, then set HOR ZEROING and VERT ZEROING adjustments at rear of instrument for CRT zero deflection.

d. Patch received signal into input jacks.

e. Set input termination switch to match source impedance of received signal, and set NOMINAL FREQUENCY switch to nominal frequency of received signal. If frequency of received signal is within ± 8% of frequency indicated by setting of NOMINAL FREQUENCY switch, and if level of received signal is within ± 4.5 dB of level indicated by setting of LEVEL ADJ switch, DO NOT READ lamp will be off.

f. NOTE: The DO NOT READ lamp, in the normal off position, indicates that the Phase-Lock Loop is locked to the signal, and that the AGC loop is near the center of its operating range, thus providing equal margins for positive and negative in-phase transient excursions. Even though steady-state conditions are such that the DO NOT READ lamp is off, large transient excursions may cause lamp to go on momentarily. This will not affect accuracy of display. If DO NOT READ lamp is on steadily, it indicates that the quiet-tone component of the received signal is more than ± 4.5 dB from the LEVEL ADJ switch setting and/or that the quiet tone frequency is more than ± 8% from the nominal frequency. If the quiet tone frequency is within the ± 8% nominal frequency range, and the quiet tone level is between -34.5 dBm and +9.5 dBm, some LEVEL ADJ switch setting can be found at which the DO NOT READ lamp goes off. However, even if the DO NOT READ lamp stays on, the PB-1 can still be used as long as the CRT display indicates that the Phase-Lock Loop is locked to the received signal. This can be determined by means of the steps below.

g. Set the MODE switch to LEVEL, dBm and the SCALE switch to X10, and observe whether rotation of the LEVEL ADJ switch causes vertical motion of the CRT spot. If the spot cannot be moved vertically, there is either no tone in the received signal or the frequency of the received tone is more than ± 8% from the frequency indicated by the setting of the NOMINAL FREQUENCY switch.

h. To check for presence of tone, set SPEAKER switch to INPUT, SPEAKER VOLUME control to clockwise maximum position, and LEVEL ADJ switch to +5. If tone is present in input signal, it will be audible.

i. If CRT spot can be moved vertically in g. above, but cannot be centered, it is an indication that the tone level is above +9.5 dBm (if spot is above center) or below -34.5 dBm (if spot is below center). In either case, set the LEVEL ADJ switch to place the spot as close as possible to the center of the graticule. Operation will then be normal in all respects except that the linear dynamic range in the amplitude (vertical) axis of the VECTOR NOTCH mode, which is normally 12 dB, will be reduced in the direction of the offset.

4-4. MEASUREMENT OF RECEIVED SIGNAL LEVEL

a. When the MODE switch is set to LEVEL, the dBm level of the quiet-tone component of the received signal is the sum of the CRT vertical deflection in dB (multiplied by the SCALE factor indicated by the setting of the SCALE switch) and the dBm level indicated by the setting of the LEVEL ADJ switch at which the DO NOT READ lamp remains off.

b. Set MODE switch to LEVEL and SCALE switch to X10.

c. Rotate LEVEL ADJ switch to setting at which DO NOT READ lamp remains off. CRT spot will be at some position along vertical centerline of graticule. The vertical scale of the graticule is linear in dB. Note the spot deflection on the graticule, multiply by the SCALE factor (indicated by the SCALE switch setting), and add algebraically to the level indicated by the LEVEL ADJ switch setting. The result is the absolute signal level in dBm. (This level is correct only if source impedance matches PB-1 input impedance selected by setting of input termination switch.)

d. To increase resolution of reading, rotate SCALE switch clockwise to maximum position (smallest SCALE multiplier) at which CRT spot still remains on screen. Multiply vertical deflection in dB by SCALE factor, and add to level indicated by LEVEL ADJ switch setting).

e. NOTE: When the MODE switch is at LEVEL, the vertical deflection is proportional to the AGC control voltage, which in turn is logarithmically related to the level of the quiet tone, so that the vertical scales of the graticule can be calibrated in dB. The AGC loop regulates the signal level with a time constant of 50 milliseconds so that it will follow amplitude jitter at frequencies from DC to a few Hz. Such amplitude jitter will appear as vertical motion of the CRT spot. One dB of vertical motion is equivalent to about ± 6% amplitude jitter in the frequency range below one Hz. (Amplitude jitter at higher frequencies will not be displayed in this mode). Erratic vertical deflection of the spot is indicative of a very noisy channel. Gain steps and gain hits may also be observed in the LEVEL mode, subject to their rate of change and duration. However, the information that can be displayed in the LEVEL mode is quiet limited as compared with that displayed in the VECTOR NOTCH mode.

4-5. MEASUREMENT OF FREQUENCY DEVIATION OF RECEIVED SIGNAL

a. When the MODE switch is set to FREQ DEV, %/10, the deviation of the quiet tone from the specified test tone frequency (i.e., 404, 804, 1004, 1704, or 2804) selected by the NOMINAL FREQUENCY switch is displayed as a vertical deflection. The vertical scale calibration is direct reading in percent frequency deviation when the SCALE switch is set to X10.

b. To measure frequency deviation with maximum resolution, rotate SCALE switch to smallest multiplier factor for which spot remains on CRT screen. Read the vertical deflection and multiply by one-tenth of the SCALE factor.

4-6. VECTOR NOTCH MEASUREMENTS, FILTERED AND UNFILTERED

a. Set NOMINAL FREQUENCY switch to frequency of received signal, set LEVEL ADJ switch so DO NOT READ lamp is off, set MODE switch to VECTOR NOTCH, set JITTER DISPLAY switch to VECTOR. For normal FILTERED VECTOR NOTCH operation, set FILTER RANGE switch to (20-300) Hz. For UNFILTERED VECTOR NOTCH operation, set FILTER RANGE switch to UNFILTERED.

b. When the MODE switch is set to VECTOR NOTCH, the in-phase component (NNN cos wt) of Normalized Notched Noise is displayed as a vertical deflection, and the quadrature component (NNN sin wt) is displayed as a horizontal deflection. These deflections are modified by the settings of the JITTER DISPLAY and FILTER RANGE switches, which are effective only in the VECTOR NOTCH mode.

c. In-phase or amplitude disturbances deflect the CRT spot vertically; an increase in amplitude deflects the spot upward, and a decrease in amplitude deflects the spot downward. Vertical deflections can be read against the CRT graticule vertical scale, which is calibrated in percent from -6% (at the bottom) through -4%, -2%, 0%, +2%, +4%, to +6% (at the top). Phase or quadrature disturbances deflect the CRT spot horizontally; phase lead deflects the spot to the right, and phase lag deflects the spot to the left. Horizontal deflections can be read against the graticule horizontal scale, which is calibrated in degrees of arc, from -3° (at the left), through -2°, -1°, (0°), $+1^{\circ}$, $+2^{\circ}$ to 3° (at the right). Note that although the vertical scale is calibrated in percent and the horizontal scale is calibrated in degrees of arc, the SCALE switch selects the multiplier factors (X0.5, X1, X2, X5 and X10) that apply to both vertical and horizontal scales. When the SCALE switch is at X1, vertical and horizontal deflections may be read directly. For other settings of the SCALE switch, multiply the graticule vertical and horizontal readings by the SCALE multiplier factor indicated by the SCALE switch setting.

d. Until the operator becomes accustomed to reading simultaneous vertical and horizontal deflections, he may rotate the JITTER DISPLAY switch from the VECTOR setting (which permits simultaneous vertical and horizontal deflections) to the AMPLITUDE position (which permits only vertical deflection) and the PHASE position (which permits only horizontal deflection), to separate deflections in random directions into their vertical and horizontal components. Always reset the JITTER DISPLAY switch to VECTOR.

e. Deflections in random directions may also be measured against polar scale circles that are calibrated in dB from -30 dB (the unnumbered smallest circle) through -20 dB, -16 dB, -14 dB, -12 dB, and -10 dB (the largest circle). Deflections read against the polar scale circles must be added algebraically to the POLAR dB level (-20, -14, -8, 0, or +6 dB) indicated by the setting of the SCALE switch. Thus, if the SCALE switch is set to -8 dB, a disturbance that causes a radial deflection to the -14 dB circle has a level of (-8) + (-14) = -22 dB with respect to the quiet tone. If the SCALE switch is set to -20 dBm a disturbance that causes a radial deflection to the -30 dB circle has a level of (-20) + (-30) = -50 dB below the quiet tone.

4-7. DISTORTION MEASUREMENTS IN UNFILTERED VECTOR NOTCH MODE

a. Second and Third Harmonic Distortion can be measured in the UNFILTERED VECTOR NOTCH mode, as well as in the 2ND H and 3RD H modes described in Par. 4-5. Because harmonics of the test tone are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure Second Harmonic forms a four-lobe cloverleaf pattern; pure Third Harmonic forms a six-lobe pattern that is folded over into two nearly-coincident three-lobe cloverleaf patterns. These patterns may rotate continuously in the presence of frequency translation (if the distortion occurs before but not if the distortion occurs after the frequency translation), rotate through limited angles in the presence of low-frequency jitter, or expand and contract in the presence of harmonic hits. In the UNFILTERED VECTOR NOTCH mode, distortion levels in dB below quiet tone level are measured on the polar scales in the same way that random-direction radial deflections are measured, as described in Par. 4-6e.

4-8. DISTORTION MEASUREMENTS IN 2ND H AND 3RD H MODES

a. The 2ND H and 3RD H positions of the MODE switch select the second and third harmonic distortion components of the received tone for display and measurement. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase intercept distortion of the channel. Since phase intercept distortion is an uncontrolled parameter, the deflection may be in any direction. It is therefore usually convenient to read the deflection

against the circular (POLAR dB) scales. Note again that the POLAR dB markings of the SCALE switch indicate the number of dB to be added to (or subtracted from) the circle calibration. In the most sensitive scale position (-20 dB), the inner circle (-30 dB) corresponds to a separation of -50 dB; i.e., the harmonic level is 50 dB below the tone level.

b. The measurement is limited by the filter bandwidth, which is made narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement theshold (50 dB below signal level). Where it is desired to study the phase intercept distortion, a harmonically rich signal can be transmitted (TEST SOURCE position of OUTPUT SELECT switch). This raises the harmonic level above the normal noise level. Filter bandwidth can also be increased, by an optional internal modification to the PB-1.

4-9. PHOTOGRAPHING PB-1 DISPLAYS

a. Photographs of PB-1 CRT displays are always useful diagnostic aids, we well as valuable records of facility performance when taken at the time of equipment installation and after subsequent maintenance. Comparisons of display photographs of a troubled facility with earlier photographs taken when the facility was functioning properly may be extremely helpful. Polaroid cameras are especially convenient, because they provide photographs in seconds, permitting the operator to adjust aperture and shutter speed until he obtains photographs that he knows to be of satisfactory quality. The Polaroid Model CR-9 Land Oscilloscope Camera, with the Polaroid Model 33-18 Hood, is a low-cost unit that takes satisfactory photographs of the PB-1 CRT display.

b. To make photographs of the PB-1 display with the Polaroid CR-9, set the camera lens aperture to f8, and set exposure time to 1/30 second.

c. Adjust PB-1 FOCUS, INTENSITY, and SCALE ILLUM controls to give a well-defined CRT trace that is slightly brighter than the illuminated graticule lines. Take experimental photographs as required, readjusting the INTENSITY and SCALE ILLUM controls until satisfactory photographs are obtained.

d. NOTE: Always record PB-1 settings for each photograph (e.g., on the rear of the photograph), so that the displays can be quantified at any subsequent time.

4-10. Photographing VECTOR NOTCH Mode Displays

a. Where possible, photographs should be taken at the same SCALE switch setting, to permit direct comparisons with other photographs taken at the same time and with record photographs taken at previous times, such as after the last previous maintenance. A SCALE switch setting of X5 is generally useful.

b. Where possible, photographs of VECTOR NOTCH displays should be taken in all three FILTER RANGE switch positions; i.e., (20-300) Hz, (20-600) Hz, and UNFILTERED.

4-11. Photographing Harmonic Mode Displays

a. In those cases of harmonic distortion with high spot mobility, a 1/30 second exposure is not long enough. For this case, extinguish the SCALE illumination, reduce the trace INTENSITY and use a manually timed exposure. Experiment with INTENSITY and aperture (F number) for best results. The magnitude of harmonic distortion is sufficiently variable that a suggested SCALE setting can not be given.

b. When the harmonic display is a stationary spot, there is no point in photographing it.

4-12. INTERPRETATION OF PB-1 DISPLAYS

4-13. GENERAL

a. The illustrations on Pages 6 through 9 of the PB-1 Brochure at the end of Section I represent a catalog of PB-1 displays corresponding to various conditions. Those illustrations are extremely useful aids for analysis of disturbances, either by comparison with PB-1 displays or with Polaroid photographs of the displays. Under each illustration is a description of the conditions causing the display, as well as a description of the corresponding sound output, which is a valuable auxiliary aid in diagnosis.

b. The Bradley Telcom Model 2A/2B Line Simulator can be used to cause PB-1 displays equivalent to those caused by the facility under test. The impairments in that facility can then be determined from the 2A/2B control settings that cause the equivalent display. This technique is especially useful for analyzing displays that have not been cataloged previously.

c. With practice, the PB-1 operator can learn to analyze even complex displays directly, without recourse to the aids in a. and b. above.

4-14. ANALYSIS OF DISTURBANCES IN VECTOR NOTCH MODE

a. Figures 6-1 through 7-8 of the PB-1 Brochure at the end of Section I, represent PB-1 displays with the MODE switch at VECTOR NOTCH, JITTER DISPLAY switch at VECTOR, and SPEAKER switch at NOTCH. The left hand photograph of each figure was taken with the FILTER RANGE switch at (20-300) Hz, and the right-hand photograph of each figure was taken with the FILTER RANGE switch at UNFILTERED. The (20-300 Hz) filter provides VECTOR NOTCH displays compatible with conventional Bell System and CCITT Phase Jitter test sets and with the Bradley Telcom Model 75LMA Phase and Amplitude Jitter Set. However, this filter limits the disturbance bandwidths displayed to those in the sidebands 20 to 300 Hz below the test tone and 20-300 Hz above the test tone. In contrast, the UNFILTERED VECTOR NOTCH mode provides displays showing the entire spectrum of disturbances from 30 to 3500 Hz, with a notch bandwidth so narrow that all disturbance frequencies except those within ±1 Hz of the test tone frequency may be observed.

b. In general, phase modulation causes essentially horizontal deflections, amplitude modulation causes vertical deflections, noise causes deflections at random angles, and SFI causes circular motions. If the VECTOR NOTCH pattern is much wider than it is high, phase jitter is predominant. If the pattern is higher than it is wide, amplitude jitter is predominant. If the display is equally large in all directions, the problem is noise or SFI. In all cases the background noise may be regarded as modulating the modulation disturbance; thus, PM plus noise produces a disturbance pattern in which the amount of PM can be estimated by subtracting the vertical deflection from the horizontal deflection.

c. An idea of the predominant jitter frequency can be obtained by operating the FILTER RANGE switch. Frequencies in the (20-300) Hz range will appear when the FILTER RANGE switch is set to (20-300) Hz and when it is set to (20-600) Hz. Frequencies in the (300-600) Hz range will appear when the FILTER RANGE switch is set to (20-600) Hz, and will disappear when the switch is set to (20-300) Hz. If there is a predominant single frequency in the modulation pattern, this can be heard on the speaker and its frequency estimated. For low-frequency jitter, either the UNFILTERED VECTOR NOTCH mode or the FREQ DEV mode may be used.

d. In the detection of modulation impairments by the PB-1, the notched noise is translated downward in frequency by the amount of the test tone and is thus centered at dc with the lower sideband folded back onto the upper sideband. This is accomplished by an internal modulator which multiplies the notched noise by the reference tone. At the same time,

the same modulator translates the notched noise up to twice the tone frequency, because the modulator produces the sum as well as the difference frequencies of its two inputs. In the (20-300) Hz position of the FILTER RANGE switch, the double-tone-frequency components are filtered out, so that only the dc-centered sidebands are displayed. In the UNFILTERED position, both the dc-centered and double-tone-frequency sidebands are displayed. Modulation impairments thus show up two ways in the UNFILTERED mode. This is really a reflection of the instrumentation used to reduce them to a display and not a picture of what is actually happening to the tip of the tone vector. It is useful because it 'flags' or calls attention to the modulation impairments, allowing them to be observed even in the presence of a larger amount of noise.

e. In the UNFILTERED VECTOR NOTCH mode, phase modulation appears as two circles that are tangent to the vertical axis at the origin, and amplitude modulation appears as two circles that are tangent to the horizontal axis at the origin. Transient phase phenomena appear as one circle to the right or left of the vertical axis at the origin, and transient amplitude phenomena appear as one circle above or below the horizontal axis at the origin. Low-frequency modulation appears as circles that alternate from one side to the other of the tangent axis, growing and shrinking as they alternate. This process occurs at the jitter frequency. The oscillation frequency may be determined by counting the cycles which occur in a timed interval. The jitter amplitude may be measured by noticing the peak amplitude of the oscillatory motion. The oscillating figure is more or less distinctly delineated, depending on the relative magnitude of the low frequency jitter with respect to the remaining impairments, but the magnitude of oscillation may always be accurately estimated because the pattern motion is distinct, i.e., the edge of the pattern moves by the jitter magnitude. The measurement of jitter frequency is important because all low frequency jitter meters (including the Bradley Telcom Model 75 LMA, as well as the PB-1), start to roll off at 3 Hz. However since the jitter frequency can be observed, the curve below (Figure 4-1) can be used to correct the reading. The majority of the cases of low-frequency jitter observed with the PB-1 have displayed a jitter frequency of between 1 and 2 Hz and a corrected jitter magnitude in excess of 25 degrees.

f. Both Coincidence Hits and Impulses cause radial deflections in random directions. Coincidence Hits are generally slower than Impulses, so that noise may be generally seen on the Coincidence Hit, but not on the Impulse. In addition, Coincidence Hits generally cause a pinging sound, while Impulses generally cause a popping sound.

g. Narrow dropouts cause vertical deflections even though they may, if narrow enough, cause a popping sound very much like that of an impulse. Consistently vertical impulse-like transients (acoustically) are really brief gain hits. Similarly, consistently horizontal impulse-like transients are really brief phase hits.

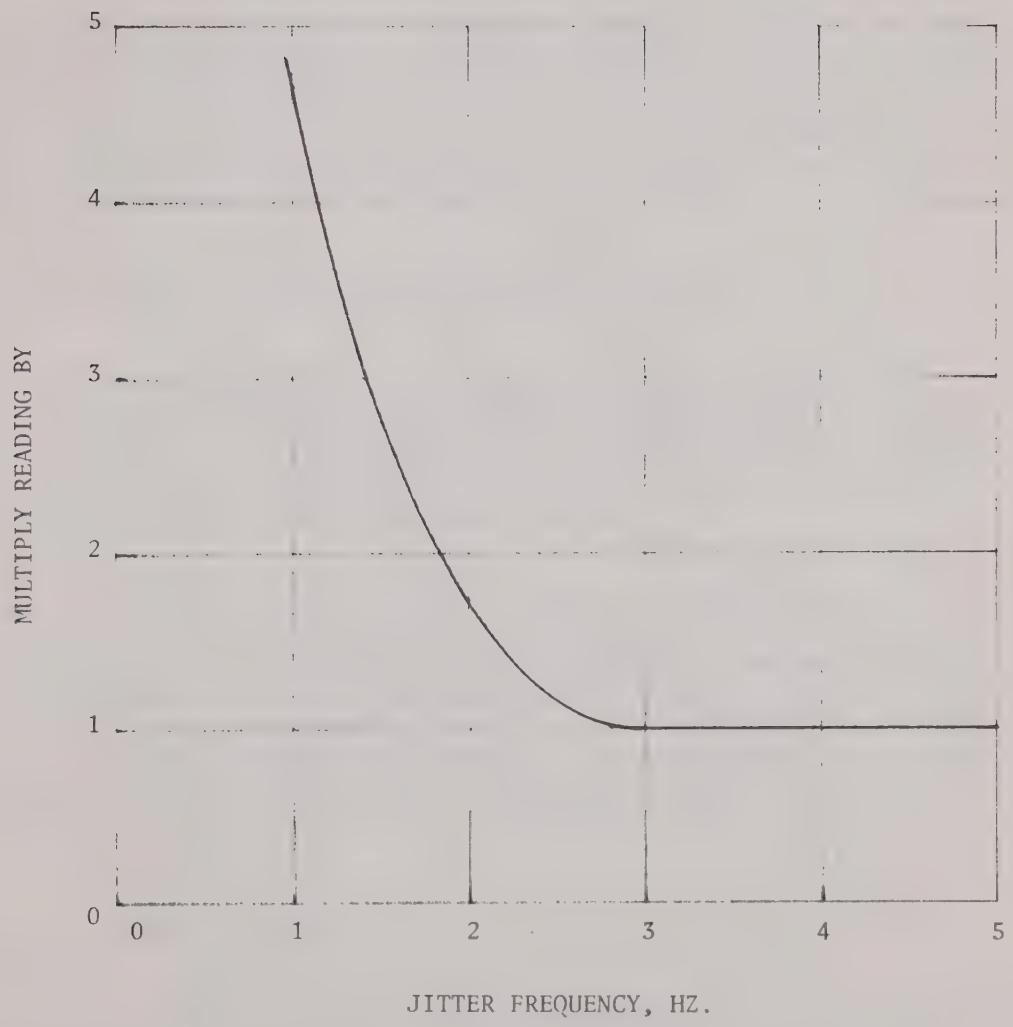

Figure 4-1 Correction For Jitter at Low Frequencies

h. FDM channels (e.g., L and N carriers) tend to have tone-correlated phase disturbances. FDM systems in which the demodulation reference is transmitted along the signal have failure modes in which low-frequency phase jitter predominates. FDM systems with an independent sync chain have predominant jitter in the 20-300 Hz passband. These latter systems may display some varying phase-intercept distortion (slow phase hit) or continuous small phase hits. Frequently these latter hits are brief in duration.

i. PCM systems (e.g., T-carriers) are characterized by noise-like disturbance patterns, which are actually complex Lissajous patterns in which the in-phase disturbance usually exceeds the quadrature disturbance. T-carrier noise patterns may have peculiar systematic shapes which vary quite noticeably with tone frequency as it affects the sampling frequency foldback products. The acoustic output has a characteristic easily identifiable sound like that of gears grinding.

4-15. DISTORTION ANALYSIS IN UNFILTERED VECTOR NOTCH MODE

a. Figures 8-1 through 8-4 of the PB-1 Brochure show Second and Third Harmonic Distortion in the UNFILTERED VECTOR NOTCH mode. Such distortion is visible in the UNFILTERED VECTOR NOTCH mode, but is out of the passbands of the (20-300) Hz and (20-600) Hz filters for test tones above 800 Hz. Figures 8-1 through 8-4 of the PB-1 Brochure are thus for the UNFILTERED VECTOR NOTCH mode only.

b. Because harmonics of the test tone are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure Second Harmonic forms a four-lobe cloverleaf pattern; pure Third Harmonic forms a six-lobe cloverleaf pattern that is folded to make two nearly-coincident three-lobe cloverleaf patterns. Continuously rotating patterns indicate that frequency translation is occurring after the distortion. Rotation of the pattern through limited angles indicates low-frequency jitter. Expanding and contracting patterns indicate harmonic hits.

4-16. HARMONIC DISTORTION ANALYSIS IN THE 2ND H AND 3RD H MODES

a. The 2ND H and 3RD H positions of the MODE switch select the second and third harmonic distortion components of the received tone for display and measurement. Figure 9-1A in the PB-1 Brochure is a typical 2ND H or 3RD H display. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase intercept distortion of the channel. Since phase intercept distortion is an uncontrolled parameter, the deflection may be in any direction.

b. When frequency translation is present, the phase intercept distortion angle changes continuously at a constant rate and the spot moves in a circular path, as shown in Figure 9-1B of the PB-1 Brochure. The impairment location causing it is shown in Figure 8-5. Note that at the Receive Terminal, the frequency of distortion content $k_T \cos (2wt + st)$, differs from twice the frequency of the fundamental, $\cos 2(wt + st)$ by the amount st. This is the equivalent of an SFI input at a beat frequency of st.

c. When second harmonic distortion, $k_R \cos (2wt + 2st)$ is introduced at the receive terminal, after the frequency translation, it is distortion of the received frequency; it is thus exactly double the received frequency and produces a stationary spot. In Figure 9-1C, note that the circle radius (k_T) corresponds to the distortion which occurs ahead of the frequency translation; the offset (k_R) of the center of the circle corresponds to the distortion which has occurred after the frequency translation; and the rate at which the circle is traversed by the spot is a measure of the frequency of translation. The foregoing analysis may be extended to third harmonic distortion.

d. There may be multiple frequency translation sources as well as other phenomena which cause variations in the phase intercept distortion angle. Phase hits cause intermittent angular motion of the spot. Phase modulation causes oscillatory angular motion of the spot. Filters limit the display bandwidth in the harmonic modes so that only low frequency jitter can be thus observed. There may also be harmonic amplitude hits, usually involving PCM carrier, which cause radial motion of the spot. There are normally multiple distortion sources although in a trouble situation, usually one will predominate. These phenomena may occur at any voice appearance in the transmission path, with unpredictable phase intercept distortion between their point of generation and the final output. The result is spot motion in random directions. The operational significance of the above is that if the distortion spot displays high mobility it is an indication that the channel will have trouble passing data.

4-18. PHASE INTERCEPT DISTORTION

a. The time delay suffered by any frequency component passing thru a transmission medium is the slope of the line joining that point on the curve with the origin on a phase vs. frequency plot. One condition required for undistorted transmission of a complex wave shape is that the phase vs. frequency curve (plotted in linear units, and extrapolated down to DC) be a straight line passing through the origin. This is the response corresponding to a pure time delay. The slope of this line is the time delay, t. Dimensionally, $\phi/w = t$; Radians/(Rad/Sec) = Sec. Intuitively there is no time domain waveshape distortion because all frequency components have the same time delay and therefore arrive in the same relative phase at the far end as they leave at the launching end.

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PB-1 FACILITY EVALUATION REPORT BY _____ DATE _____

FROM -

VIA -

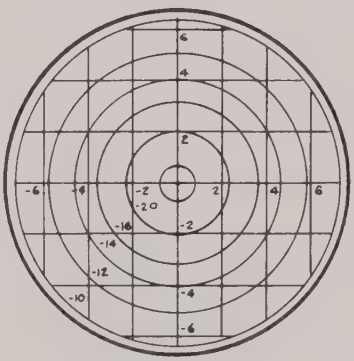
TO -

Received Tone Level - ____ dBm Frequency - ____ Hz

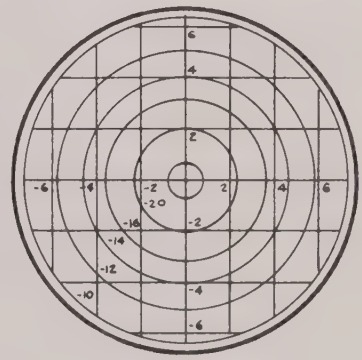
MODE - VECTOR NOTCH, Steady State Characterization

DISPLAY FILTER	20 to 300 Hz	UNFILTERED
Max. Horizontal Excursion	____ degrees	____ degrees
Max. Vertical Excursion	____ percent	____ percent
Max. Radial Excursion	____ dB	____ dB

Adjacent graticule drawings may be used or sketch display pattern, or scope photos may be attached.



SCALE X __



SCALE X __

Predominant Impairment - If several impairments are present, indicate relative magnitude.

Noise	____	____
Phase Jitter	____	____
Low Frequency Phase Jitter		____ amplitude
		____ frequency
Amplitude Jitter	____	____
SFI	____	____
Harmonic Distortion	____	____

Decrease received tone level 10 dB and remark on any changes in above.

MODE - VECTOR NOTCH, Transient Characteristics

Observation interval ____minutes.

Phase Hits ___hits over ___Degrees

Gain Hits ___hits over ___Percent

Impulse Hits ___hits over ___dB

Use the SPEAKER in the NOTCH position to assist in identifying hits. Note difference between modulation hit "ping" and impulse noise "pop".

HARMONIC MODES	2nd	3rd
Max. Excursion	____ dB	____ dB
Min. Excursion (closest point to origin)	____ dB	____ dB
Frequency Translation	____ Hz	____ Hz
Circle Diameter	____ dB	____ dB
Circle Offset	____ dB	____ dB

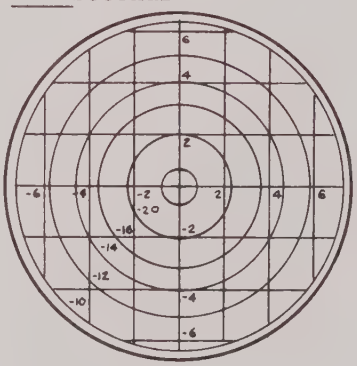
Spot Mobility in ____2nd or ____3rd mode (check one)

Moves ____inches in ____seconds at ____dB SCALE setting

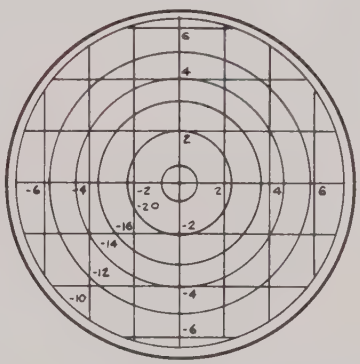
Oscillatory - from ____ to ____o'clock in ____seconds

Radial - ____dB in ____seconds

Adjacent graticule drawings may be used to sketch display pattern, or scope photos may be attached



SCALE __ dB



SCALE __ dB

Decrease tone level 10 dB from nominal and remark on any changes in above.

ACCOUSTIC (NOTCHED NOISE)	Yes	No
Noise hiss	_____	_____
Crosstalk	_____	_____
Single tones audible	_____	_____
Multiple tones audible	_____	_____

Switch SPEAKER switch between INPUT and NOTCH. Audible tones in NOTCH position are higher __, lower __, or surrounding __ test tone frequency. Note PCM, FDM, and copper have distinctive accoustic signatures. Comment on audible presence of modulation hits__, impulse hits__, harmonic hits__.

b. Note that a perfectly linear phase vs. frequency curve (zero envelope delay distortion) is not a sufficient condition for low base-band distortion because, referring to Figure 9-2 then the component of frequency w_1 has a time delay ϕ_1/w_1 which is entirely different from that of the w_2 component, ϕ_2/w_2. This distortion is a result of the angle at the extrapolated intersection of the phase vs. frequency curve with zero frequency. This is known as the phase intercept distortion. It is an uncontrolled parameter in most communications systems.

c. The angular displacement of the spot for either second or third harmonic distortion measurement is a measure of the phase intercept distortion. In the mechanization of the instrument, the received tone, $\cos (wt + \phi_w)$ is tracked. It is then doubled, i.e., $\cos (2wt + 2\phi_w)$. The phase and amplitude of the second harmonic $\cos (2wt + \phi_{2w})$ is plotted with respect to the double frequency tone as a reference. Referring to Figure 9-3 which is a phase vs. frequency plot, the phase difference between $\cos (2wt + 2\phi_w)$ and $\cos (2wt + \phi_{2w})$ is $(2\phi_w - \phi_{2w})$. This is the deflection angle of the harmonic distortion spot. It is also the phase intercept distortion based on measurement at frequencies w and 2w. A similar observation is true with respect to the third harmonic.

d. Angular motion of the harmonic 'spot' corresponds to changes in phase intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase intercept distortion due to that source. However, a multiplicity of distortion sources may exist in a transmission channel relative to a multiplicity of phase intercept distortion sources. The case of frequency translation described above is commonly encountered.

e. The measurement is limited by the filter bandwidth. This must be narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50 dB below signal level). Where it is desired to study the phase intercept distortion a harmonically rich signal can be transmitted (TEST SOURCE position of OUTPUT SELECT switch). This raises the harmonic level above the noise level. Filter bandwidth can also be increased, by an optional internal modification to the PB-1.

b. Note that a perfectly linear phase vs. frequency curve (zero envelope delay distortion) is not a sufficient condition for low baseband distortion because, referring to Figure 9-2 then the component of frequency w_1 has a time delay ϕ_1/w_1 which is entirely different from that of the w_2 component, ϕ_2/w_2. This distortion is a result of the angle at the extrapolated intersection of the phase vs. frequency curve with zero frequency. This is known as the phase intercept distortion. It is an uncontrolled parameter in most communications systems.

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d. Angular motion of the harmonic 'spot' corresponds to changes in phase intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase intercept distortion due to that source. However, a multiplicity of distortion sources may exist in a transmission channel relative to a multiplicity of phase intercept distortion sources. The case of frequency translation described above is commonly encountered.

e. The measurement is limited by the filter bandwidth. This must be narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50 dB below signal level). Where it is desired to study the phase intercept distortion a harmonically rich signal can be transmitted (TEST SOURCE position of OUTPUT SELECT switch). This raises the harmonic level above the noise level. Filter bandwidth can also be increased, by an optional internal modification to the PB-1.

ALIGNMENT PROCEDURES

5-1. GENERAL

a. The alignment procedures described in this section should be performed only by personnel familiar with the operation of the PB-1 VF Line Analyzer and with the appearance of its displays.

b. Perform the alignment in the sequence given by Pars. 5-19 through 5-39, for minimum interaction between adjustments.

c. Perform alignment only with equipment that meets the specifications given in Par. 5-2.

5-2. EQUIPMENT REQUIRED FOR ALIGNMENT

a. Oscillator #1: frequency range, 300 to 3000 Hz; output level range, -50 dBm to +10 dBm; output impedance, 600 ohms ±2% balanced; phase jitter, less than 0.1°; amplitude jitter, less than 0.1%; total distortion, less than 1% (-40 dB). Frequencies must be settable within 0.1% and output levels must be settable within 0.2 dB. The TONE FREQUENCY Oscillator of the Bradley Telcom Model 2A/2B Line Simulator meets these specifications.

b. Oscillator #2: identical to Oscillator #1. The MODULATION FREQUENCY Oscillator of the Model 2A/2B Line Simulator meets these specifications.

c. Oscillator #3 is required only for alignment of 2ND H and 3RD H modes of the PB-1. Specifications are: output frequency range, 300 to 3300 Hz; output level, settable to 0 dBm; output impedance, 600 ohms ±2% balanced; phase jitter, less than 0.1°; amplitude jitter less than 0.1%; 2nd harmonic distortion less than 0.1% (-60 dB); 3rd harmonic distortion less than 0.1% (-60 dB); total distortion less than 0.1% (-60 dB). The Bradley Telcom Model PB-O and PB-OR Oscillators meet these specifications.

d. Cathode Ray Oscilloscope with Y versus X (Vectorscope) display capability, and with horizontal time base for Y versus T display capability.

e. High-Impedance DC Voltmeter: input impedance, 20,000 Ω/V minimum.

f. Level Meter

g. Miscellaneous patch cords, leads, tools, etc., as required.

5-3. NOTES ON USE OF TEST OSCILLATORS

a. Some PB-1 alignment procedures employ Oscillator #1 as a source of test tones at specified levels (usually 0 dBm), and Oscillator #2 as a source of single frequency interference (SFI) tones, usually at levels of 25% (-12 dB) or 10% (-20 dB) of the test tone level.

b. If the TONE FREQUENCY oscillator in the 2A/2B Line Simulator is used as Oscillator #1, to provide the test tone, and the MODULATION FREQUENCY oscillator is used as Oscillator #2, to provide the SFI tone, the SINGLE FREQUENCY INTERFERENCE level control can be set directly in percent SFI with respect to the OUTPUT LEVEL setting of the 2A/2B. SINGLE FREQUENCY INTERFERENCE level settings of 25% or 10% will then give SFI levels of -12 dB or -20 dB respectively with respect to the OUTPUT LEVEL setting. Furthermore, the two tones are added internally in the 2A/2B Line Simulator, and their sum appears at a single 600 ohm output. If this output is patched to the PB-1 INPUT jacks, and the PB-1 INPUT termination switch is set to 600 Ω, the 2A/2B Simulator and the PB-1 Analyzer will be properly matched, and the output levels of the two oscillators will be correct.

c. If Oscillators #1 and #2 are separate units, and their outputs are added by paralleling at the PB-1 input jacks mismatch may occur, because the load impedance seen by either oscillator is equal to the output impedance of the other oscillator in parallel with the input impedance of the PB-1. Thus, if the output impedances of the oscillators and the input impedance of the PB-1 are each 600 ohms, then each oscillator will see a mismatched load of 300 ohms instead of a matched load of 600 ohms; and the resulting mismatch will cause the output levels of both oscillators to be in error with respect to the settings of their level controls. In this case, set the PB-1 input termination switch to BRIDGE, which represents an input impedance of 25,000 ohms. This is so high compared to 600 ohms, that each oscillator will be effectively terminated by the 600 ohm output impedance of the other oscillator, and the output level of each will then correspond to its level control setting.

d. When both Oscillators #1 and #2 are used in any of the alignment procedures of Pars. 5-19 through 5-39, the PB-1 input termination switch should be set to the appropriate setting. If Oscillators #1 and #2 are the TONE FREQUENCY and the MODULATION FREQUENCY oscillators of the Model 2A/2B Line Simulator, as in b. above, the appropriate setting of the PB-1 input termination switch is 600 Ω. If Oscillators #1 and #2 are separate units with 600 ohm output impedances as in c. above, the appropriate setting of the input termination switch is BRIDGE.

5-4. REMOVAL OF CASE AND REAR PANEL

5-5. CAUTION: Do not remove case with power cord connected to line.

5-6. DANGER: VOLTAGES UP TO 1200 VDC APPEAR ON REAR CIRCUIT BOARD WHEN POWER IS APPLIED TO PB-1. Do not touch rear circuit board when power is applied, except with insulated tools. When making screwdriver adjustments, grasp screwdriver only by insulated handle.

5-7. Removal of PB-1 Case and Rear Panel

a. To remove case, invert PB-1 and remove six 6-32 screws (three screws along each side) that retain case to bottom of frame. Then spread bottom edges of case sufficiently to clear circuit boards at sides of frame, and pull case from frame.

b. To remove rear panel, loosen two 6-32 screws at bottom of panel, and then remove four acorn nuts that fasten panel to frame. Slide panel upwards and remove.

5-8. Removal of PB-1R Case and Rear Panel

a. To remove case, remove two 6-32 screws at left rear of instrument as viewed from rear, and slide case backward from panel.

b. To remove rear panel, remove from acorn nuts that fasten panel to frame. Slide panel to right and remove.

5-9. IDENTIFICATION OF CIRCUIT BOARDS AND ADJUSTMENTS.

5-10. CAUTION: Do not reset any internal adjustments except in accordance with the sequence of alignment procedures given in Pars. 5-21 through 5-39. However, the HOR ZEROING adjustment (P3) and the VERT ZEROING adjustment (P4), which are externally accessible through small holes near the top of the rear panel, may be reset at any time after warmup.

5-11. REAR CIRCUIT BOARD (Figure 5-1)

5-12. The rear circuit board contains all power supplies, CRT deflection amplifiers, and potentiometer adjustments P1 through P8.

a. P1 is the CRT intensity adjustment that is operated by the INTENSITY control on the front panel.

b. P2 is the CRT focus adjustment that is operated by the FOCUS control on the front panel.

c. P3 is the HOR ZEROING adjustment.

d. P4 is the VERT ZEROING adjustment. P3 and P4 are accessible through small holes at the top of the rear panel. After a ten-minute warmup, P3 and P4 may be used to adjust the centering of the spot with the MODE switch at VECTOR NOTCH and the JITTER DISPLAY switch at ZERO.

e. P5 is the horizontal gain equalizing control. The vertical deflection sensitivity of the CRT is inherently greater than the horizontal deflection sensitivity, and P5 is used to make the overall horizontal deflection sensitivity equal to the overall vertical deflection sensitivity as described in Par. 5-27.

f. P6 is the horizontal astigmatism adjustment. It sets the current in the horizontal deflection amplifier, and thus the average horizontal deflection plate voltage. When P6 is set in accordance with Par. 5-22, the average horizontal deflection plate voltage is equal to the CRT Ultor (screen) voltage, and horizontal astigmatism is minimized.

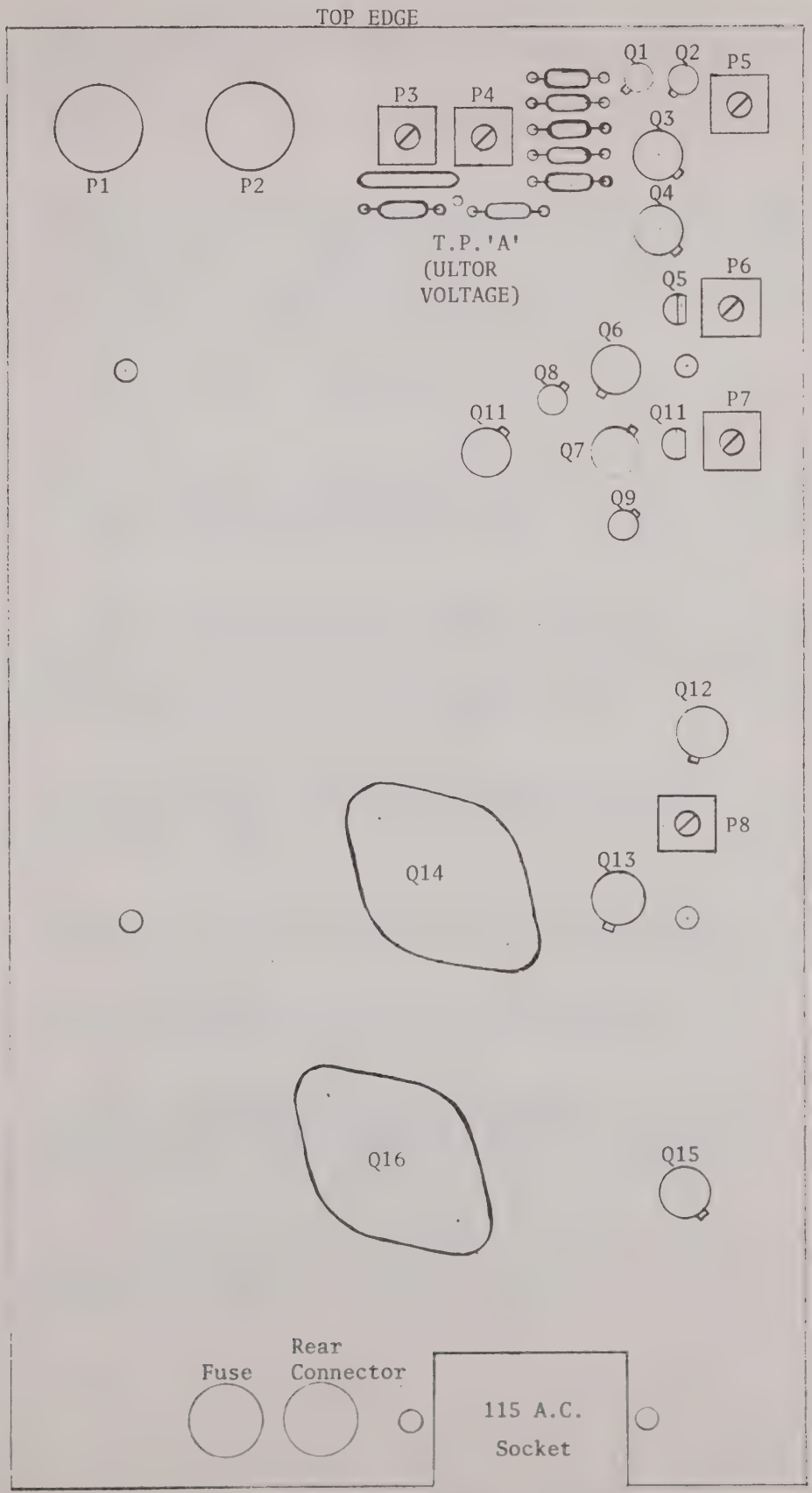


FIG. 5-1 REAR BOARD LAYOUT, component side

g. P7 is the vertical astigmatism adjustment. It sets the current in the vertical deflection amplifier, and thus the average vertical deflection plate voltage. When P7 is set in accordance with Par. 5-22, the average vertical deflection plate voltage is equal to the CRT Ultor (screen) voltage, and vertical astigmatism is minimized.

h. P8 is the Regulated ±12 VDC Supply adjustment. The Regulated ±12 VDC Supplies are set at about ±12.3 VDC. Do not reset potentiometer P8 unless absolutely required, because the calibration will be affected, necessitating readjustment of the spurious harmonic suppression controls in the phase-lock loop. If readjustment of P8 is required, follow the procedure given in Par. 5-21.

5-13. IAGC (INPUT AND AGC) CIRCUIT BOARD (Figure 5-2)

5-14. The IAGC board is the top board in the PB-1, and the left-hand board (as viewed from the front) of the PB-1R. It contains potentiometer adjustments P9 through P14.

a. P9 is the NNN Cos wt Gain Adjustment. It affects the vertical deflection sensitivity in the VECTOR NOTCH position of the MODE switch, and also affects the AGC loop gain. P9 is set in accordance with Par. 5-31 so that the vertical deflection sensitivity in the UNFILTERED VECTOR NOTCH mode matches the graticule calibration.

b. P9A is the NNN Cos wt Coarse (DC) Balance Adjustment. It affects the coarse in-phase null adjustment of the AGC loop. It is set in accordance with Par. 5-23.

c. P10 is the NNN Cos wt Multiplier #1 Balance Adjustment.

d. P11 is the NNN Cos wt Multiplier #2 Balance Adjustment. Potentiometers P10 and P11 are set in accordance with Par. 5-29.

e. P12 is the dBm LEVEL Calibration Adjustment. It affects the vertical gain in the dBm LEVEL mode, as well as the range of input levels (approximately ±4 dB) within which the DO NOT READ lamp is off. P12 is set in accordance with Par. 5-35.

f. P13 is the AGC Voltage Zero Level Adjustment. It sets the CRT zero vertical deflection point in the dBm LEVEL mode. P13 is set in accordance with Par. 5-35.

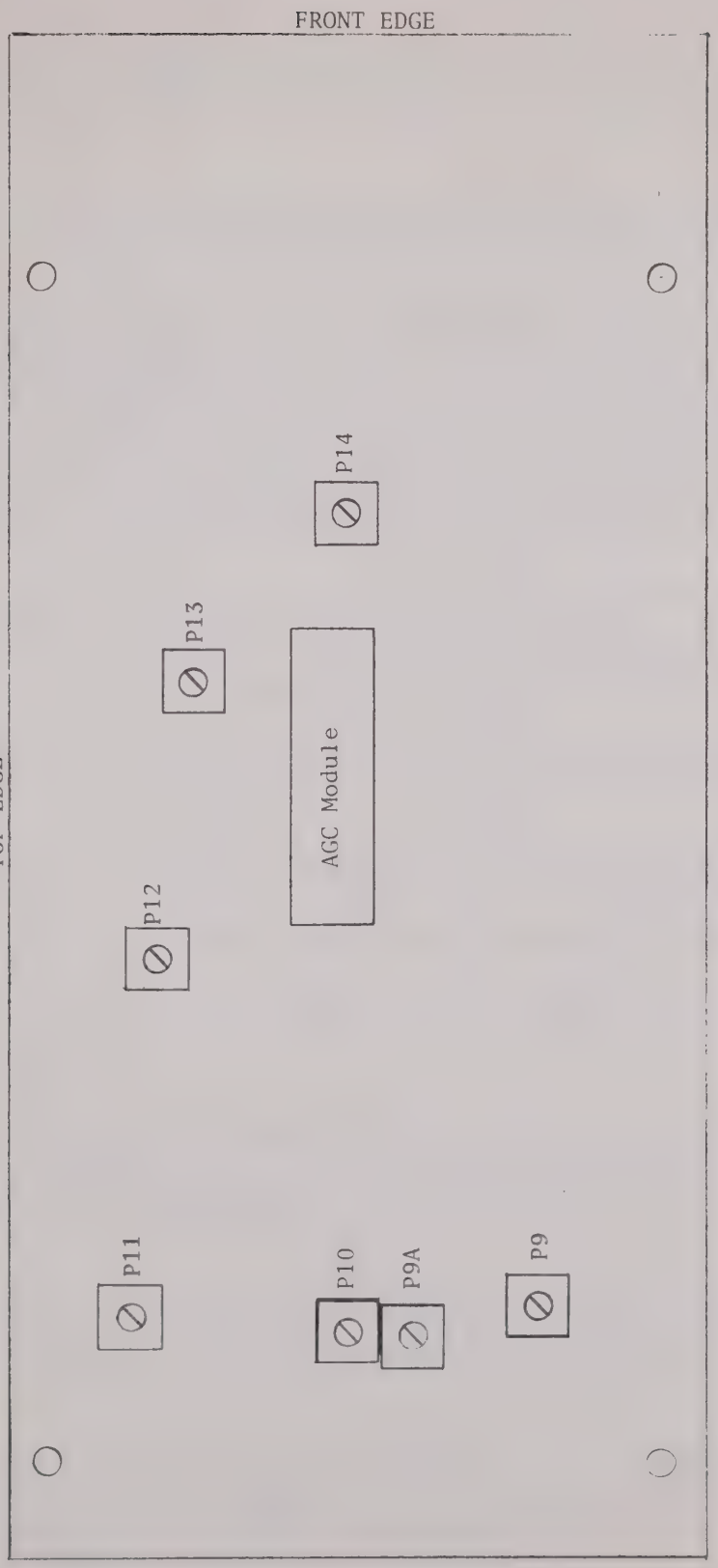


FIG. 5-2 INPUT AND AGC BOARD, component side
(Top Board in PB-1)

g. P14 is the AGC Loop Gain Adjustment. It is set for an AGC time constant equivalent to the phase-lock loop time constant, which is approximately 1/7 second for 90% recovery. P14 is set in accordance with Par. 5-34.

5-15. PPLL (PRECISION PHASE-LOCK LOOP) CIRCUIT BOARD (Figure 5-3)

5-16. The PPLL Board is the right-hand circuit board as viewed from the front of the PB-1, and is the top board of the PB-1R. It contains potentiometer adjustments P15 through P38. Potentiometers P15 through P20 are VCO open-loop frequency adjustments, i.e., they control the VCO center frequency when the phase-lock loop is open, as in the TONE position of the OUTPUT SELECT switch. Potentiometers P15 through P20 are set in accordance with Par. 5-25. Note that the FREQ DEV %/10 calibration is affected by the settings of these potentiometers.

a. P15 is the VCO 404 Hz Open-Loop Frequency Adjustment.

b. P16 is the VCO 804 Hz Open-Loop Frequency Adjustment.

c. P17 is the VCO 1004 Hz Open-Loop Frequency Adjustment.

d. P18 is the VCO 1704 Hz Open-Loop Frequency Adjustment.

e. P19 is the VCO 2804 Hz Open-Loop Frequency Adjustment.

f. P20 is the VCO Open-Loop Frequency Adjustment for the optional sixth frequency.

g. P21 is the 2nd Harmonic Adjustment, the setting of which affects the calibration of the 2ND H mode, as well as the second-harmonic content of the normalized notched noise in all other tracking modes of operation. P21 is set in accordance with Par. 5-24.

h. P22 is the 3rd Harmonic Adjustment, the setting of which affects the calibration of the 3RD H mode, as well as all other modes that depend on the signal level of the notch. P22 is set in accordance with Par. 5-24.

i. P23 is the Phase-Lock-Loop Multiplier Gain Adjustment, which does not affect any display mode calibration, but does affect recovery time, synchronization, and response to large phase hits. P23 is set in accordance with Par. 5-39.

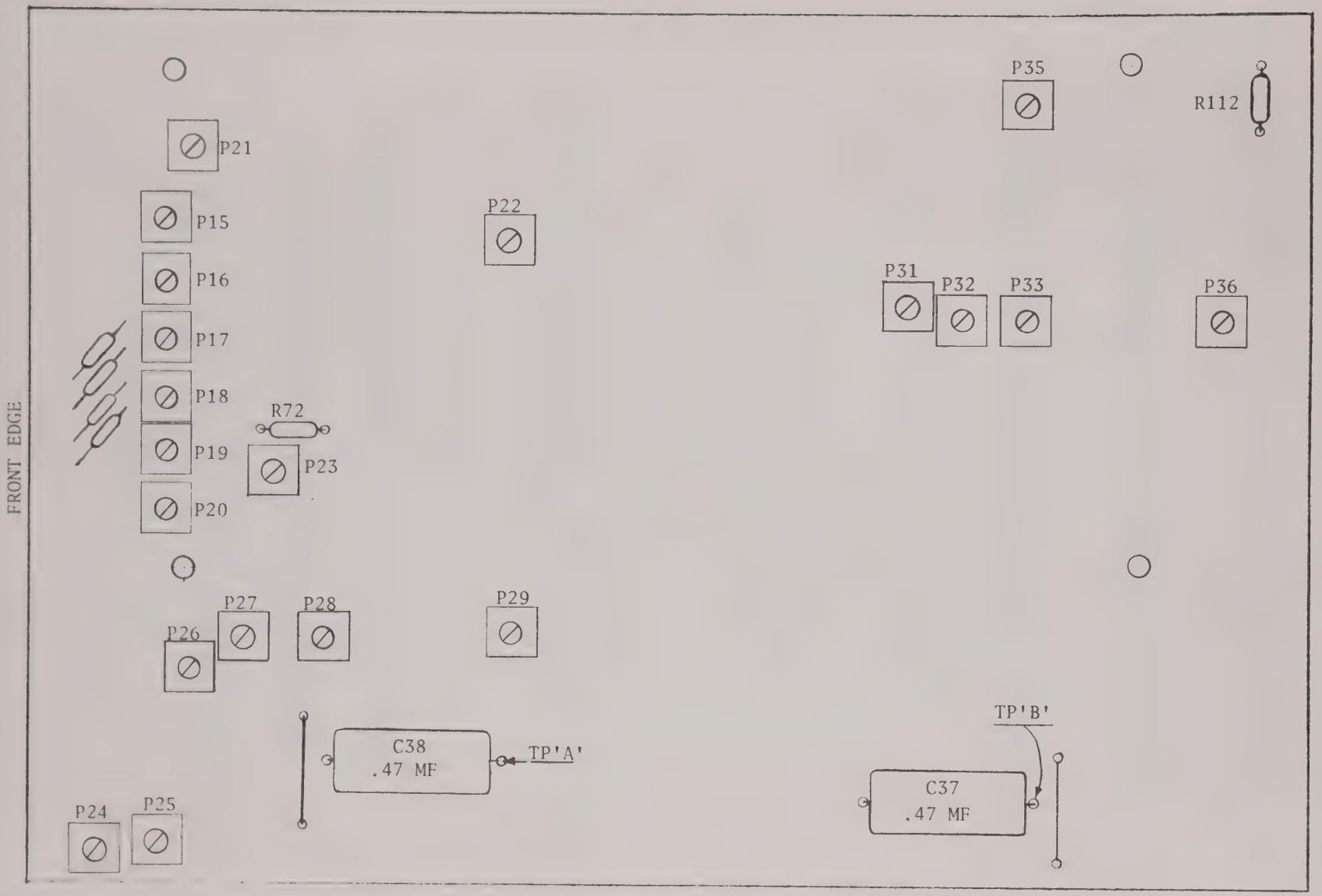


FIG. 5-3 PRECISION PHASE LOCK LOOP BOARD, component side
(Right-Hand Board as Viewed From Front of PB-1)

j. P24 is the Automatic Balance Circuit Fine Phase Adjustment. It affects the quadrature component of the residual null in the notch. P24 is adjusted in accordance with Pars. 5-23 and 5-24.

k. P25 is the Automatic Balance Circuit Fine AGC Adjustment. It affects the in-phase component of the residual null in the notch. P25 is adjusted in accordance with Pars. 5-23 and 5-24.

l. P26 is the FREQ DEV Calibration Adjustment. It sets the vertical spot deflection versus frequency deviation to match the graticule percent calibrations. P26 is set in accordance with Par. 5-36.

m. P27 is the Phase-Lock Loop Coarse Balance Adjustment. P27 is set in accordance with Par. 5-23.

n. P28 is the PLL Multiplier #1 Balance Adjustment.

o. P29 is the PLL Multiplier #2 Balance Adjustment. P28 and P29 are set in accordance with Par. 5-37.

p. P30 is an unused designation.

q. P31 is the Cos wt Output Level Adjustment. It affects both horizontal and vertical deflection scale factors in the VECTOR NOTCH, 2ND H, and 3RD H modes; and also affects the output levels in the TONE, LOC. OSC., and NOTCHED NOISE positions of the OUTPUT SELECT switch. P31 is set in accordance with Par. 5-26.

r. P32 is the NNN Sin wt DC Balance Adjustment.

s. P33 is the NNN Sin wt Multiplier #1 Balance Adjustment.

t. P34 is the NNN Sin wt Multiplier #2 Balance Adjustment. Potentiometers P32, P33 and P34 are set in accordance with Par. 5-30.

u. P35 is the NNN Sin wt Gain Adjustment. P35 is set in accordance with Par. 5-31.

5-17. HARMONIC ANALYZER CIRCUIT BOARD (Figure 5-4)

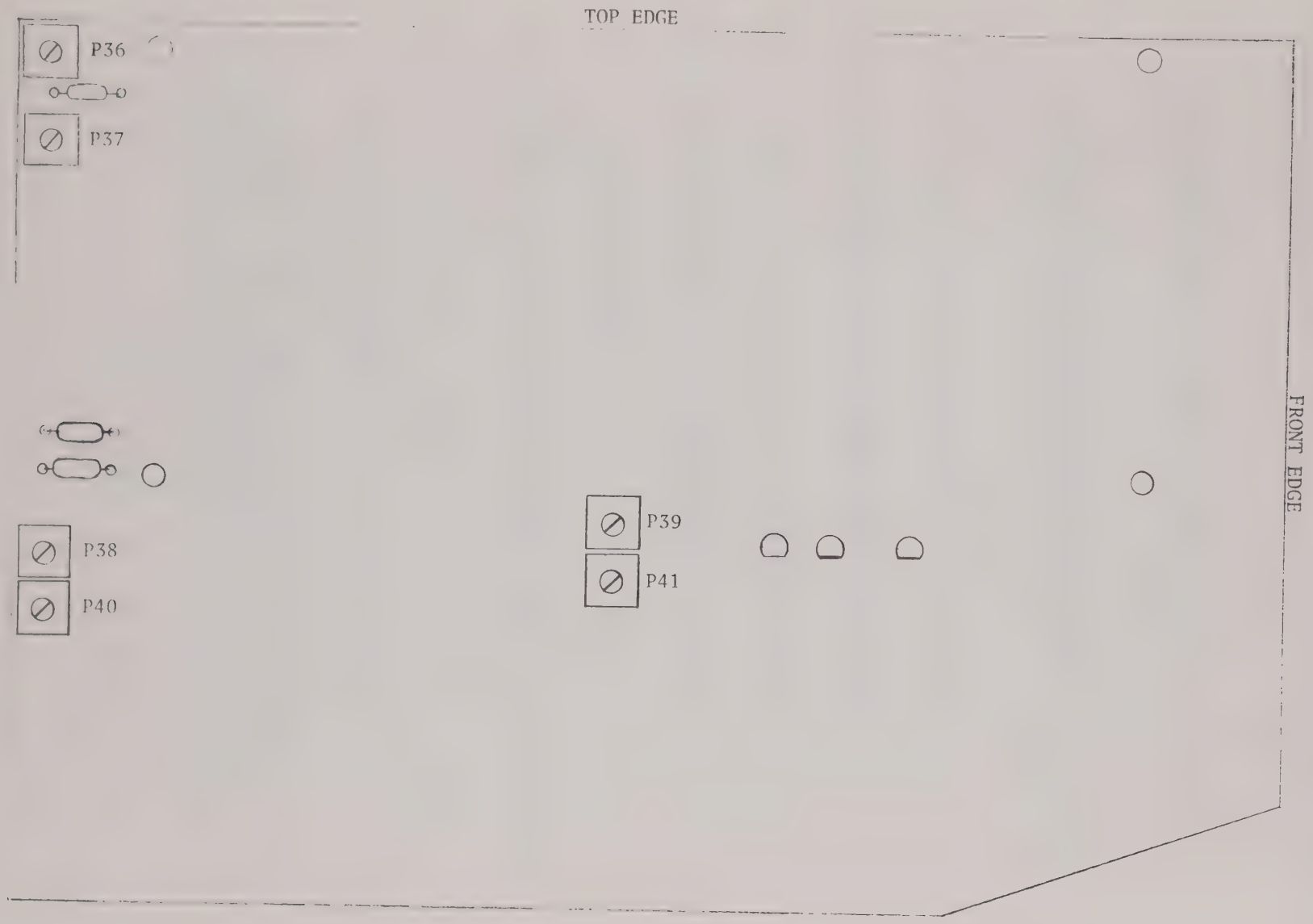


FIG. 5-4 HARMONIC ANALYZER BOARD, component side
(Left-Hand Board as Viewed From Front of PB-1)

5-18. The Harmonic Analyzer board is the left-hand circuit board as viewed from the front of the PB-1, and the bottom board in the PB-1R. It contains potentiometers P36 through P41.

a. P36 is the 2nd and 3rd Harmonic Gain Adjustment, that sets the CRT deflection sensitivity to match the graticule calibrations in the 2ND H and 3RD H modes. P36 is set in accordance with Par. 5-28.

b. P37 is the Notched-Noise Output Gain Adjustment, which sets the 0 dB and -29 dB levels of the OUTPUT LEVEL switch when the OUTPUT SELECT switch is in the NOTCHED NOISE position. P37 is set in accordance with Par. 5-38.

c. P38 is the 20-600 Hz Vertical Filter Gain Adjustment.

d. P39 is the 20-600 Hz Horizontal Filter Gain Adjustment. Potentiometers P38 and P39 are set in accordance with Par. 5-33.

e. P40 is the 20-300 Hz Vertical Filter Gain Adjustment.

f. P41 is the 20-300 Hz Horizontal Filter Gain Adjustment. Potentiometers P40 and P41 are set in accordance with Par. 5-32.

5-19. ALIGNMENT PROCEDURES

5-20. NOTE: It is important to perform all alignments and adjustments in the sequence of the following paragraphs in order to minimize interactive effects between adjustments.

5-21. ±12 VDC POWER SUPPLY ADJUSTMENT.

a. On Figure 5-1, Rear Board, locate Potentiometer P8.

b. CAUTION: Do not change the setting of P8, the regulated ±12 VDC supply adjustment, unless prepared to perform the entire alignment procedure described in the following paragraphs. The outputs of this supply affect calibrations and adjustments of various modes, expecially the settings of the spurious harmonic suppression controls in the phase-lock loop.

c. Connect PB-1 power cable to 115 VAC, and set POWER switch to ON.

d. Set voltmeter range for 12 VDC input, connect (+) lead to +12 VDC bus on back of rear board, and connect (-) lead to black circuit ground banana jack on front panel of PB-1. Note voltmeter indication. If this is +12.3 ±.05 VDC, disconnect voltmeter and perform step f. below.

e. If voltmeter indication is not +12.3 ±.05 VDC, adjust P8 so that voltmeter indication is +12.3 VDC. Disconnect voltmeter.

f. Connect voltmeter (+) lead to ground jack on panel, and connect (-) lead to -12 VDC bus on back of board. Voltmeter indication should be within ±0.01 VDC of indication for -12 VDC supply.

5-22. HORIZONTAL AND VERTICAL ASTIGMATISM ADJUSTMENTS

a. On Figure 5-1, Rear Board, locate Potentiometers P6 and P7, and Test Point A.

b. Set voltmeter range for 100 VDC input, connect (-) lead to ground jack on panel, and connect (+) lead to the CRT Ultor voltage (Test Point A in Figure 5-1). Note Ultor voltage, and disconnect (+) lead. The Ultor voltage should be 90 ±10 VDC.

c. Connect voltmeter (+) lead to the case (collector) of Q3 and then of Q4. These are the CRT horizontal deflection amplifiers. Note both voltmeter indications. The average of the Q3 and Q4 collector voltages is the average horizontal deflection plate voltage. If this is not within ± 10% of the Ultor voltage measured in step b. above, adjust P6 so that voltmeter indication equals Ultor voltage. Disconnect voltmeter (+) lead.

d. Connect voltmeter (+) lead to the case (collector) of Q6 and then of Q7. These are the CRT vertical deflection amplifiers. Note both voltmeter indications. The average of the Q6 and Q7 collector voltages is the average vertical deflection plate voltage. If this is not within ± 10% of the Ultor voltage measured in step b. above, adjust P7 so that voltmeter indication equals Ultor voltage. Disconnect voltmeter.

5-23. ADJUSTMENT OF NOTCH FOR SUPPRESSION OF INPUT TONE FUNDAMENTAL.

a. On Figure 5-2, IAGC Board, locate P9A, and
on Figure 5-3, PPLL Board, locate P24, P25 and P27

b. Set Oscillator #1 to 404 Hz, 0 dBm, and patch output into PB-1 input jacks.

c. Set PB-1 input termination switch to 600Ω, NOMINAL FREQUENCY switch to 400 Hz, and LEVEL ADJ switch to 0 dBm. The DO NOT READ lamp should be off.

d. P9A is the AGC loop coarse DC balance adjustment; it affects the in-phase component of the null in the notch. P9A should be adjusted for minimum AGC automatic balance voltage. Connect one voltmeter lead to the PB-1 panel ground jack, and connect the other lead to Test Point A on the PPLL board (Near C38 in Figure 5-3). The voltage indicated by the voltmeter is the automatic balance voltage for the AGC loop. Adjust P9A for minimum absolute value of this voltage. The minimum should be within 0 ±1 VDC.

e. P27 is the Phase-Lock Loop coarse balance adjustment; it affects the quadrature component of the null in the notch. P27 should be adjusted so that the automatic balance voltage for the phase-lock loop does not go into saturation (i.e., remains below 10-11 VDC) on any frequency range. To do this, connect one lead of the voltmeter to the panel ground jack, and connect the other lead to Test Point B on the PPLL board (Near C37 in Figure 5-3). This voltage is the PPLL automatic balance voltage. Adjust P27 to minimize the absolute value. The minimum should be within 0 ±1 VDC at 404 Hz input frequency.

f. Set Oscillator #1 frequency to 804 Hz, set PB-1 NOMINAL FREQUENCY switch to 800, and check that the voltage from Test Point B to ground remains well under the 10-11 VDC saturation level.

g. Repeat check of PLL automatic balance voltage from Test Point B to ground at 1004, 1704, and 2804 Hz.

h. P24 is the PLL automatic balance circuit fine phase adjustment (quadrature component of null in notch), and P25 is the AGC automatic balance circuit fine amplitude adjustment (in-phase component of null in notch). The following step is a preliminary adjustment of P24 and P25.

i. With Oscillator #1 and PB-1 both set for 1004 Hz, 0 dBm, adjust P24 and P25 for minimum 1004 Hz output from PB-1. This should be less than 3 to 4 mVAC. Check for minimum fundamental out at 404, 804, 1704 and 2804 Hz, but do not readjust P24 or P25 until performing the procedure of Par. 5-24.

5-24. ADJUSTMENT OF VCO FOR MINIMUM HARMONIC OUTPUT IN NOTCH

a. On Figure 5-3, PPLL Board, locate P21, P22, P24, and P25.

b. Set Oscillator #3 to 1004 Hz, 0 dBm, and patch into PB-1 input jacks, and also into CRO horizontal input. Set CRO for Vectorscope operation, and adjust CRO H and V sensitivities as required in the following steps.

c. Set PB-1 input termination switch to 600Ω; LEVEL ADJ switch switch to 0 dBm; NOMINAL FREQUENCY switch to 1000 Hz; OUTPUT SELECT switch to NOTCHED NOISE. Connect 600 ohm load and CRO vertical input across output terminals.

d. NOTE: Potentiometers P21, P22, P24 and P25 all interact, and must be iteratively adjusted to obtain successively smaller minimum vertical deflections of the Lissajous figures of the notch outputs shown in the Vectorscope displays of Figure 5-5. Figures 5-5A and 5-5B represent the outputs of two badly misaligned notches, with potentiometers P21, P22, P24 and P25 purposely set far from their correct positions. Figure 5-5C represents a typical notch output after P21 and P22 have been iteratively adjusted. Figure 5-5D represents the typically low notch output after P24 and P25 (and, if necessary, P21 and P22 again) have been iteratively adjusted. Figures 5-5E through 5-5H show typical notch outputs resulting when each of potentiometers P21, P22, P24 and P25 is separately misadjusted while the other three potentiometers remain at the positions for best notch (lowest output). In Figure 5-5E only P21 is misadjusted; in Figure 5-5F only P22 is misadjusted; in Figure 5-5G only P24 is misadjusted; and in Figure 5-5H only P25 is misadjusted.

e. P21, the 2nd Harmonic Adjustment, controls the duty cycle of the VCO triangular and square waveforms. A duty cycle of other than 50% will create a spurious second harmonic in the VCO sine wave output, and this will appear in the notched-noise output, even though the PB-1 input tone is pure. With the PB-1 OUTPUT SELECT switch at NOTCHED NOISE, the pure 1004 Hz tone from Oscillator #3 should be minimum in the notched noise, so that the CRO vertical deflection should be minimum, if there is no second harmonic created by the VCO in the PB-1. Adjust P21 for minimum vertical deflection on the CRO. This should be at least 50 dB below input tone level. (Note that P21 affects the harmonics in the harmonic display modes, and also interacts with the phase and amplitude adjustments for a best notch).

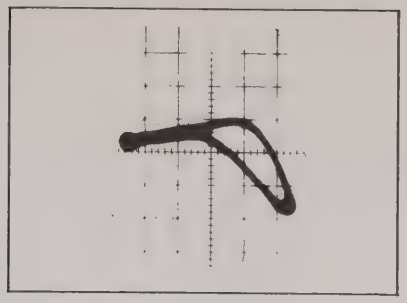


Fig. 5-5A Poor Notch, P21, P22, P24, P25 Incorrectly Set

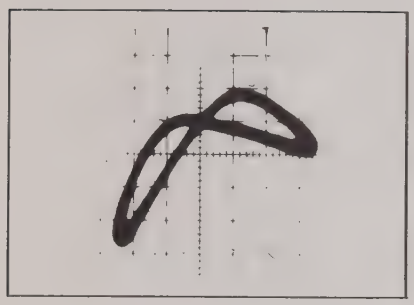


Fig. 5-5B Poor Notch P21, P22, P24, P25 Incorrectly Set

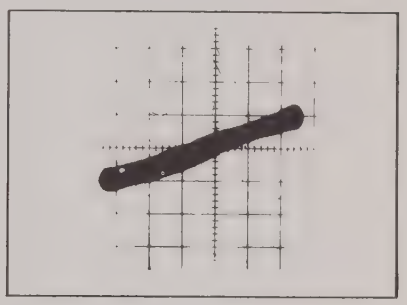


Fig. 5-5C P21, P22 Adjusted P24, P25 Maladjusted

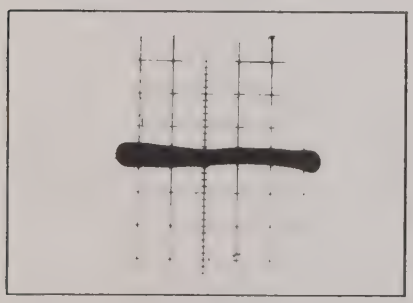


Fig. 5-5D A11 Pots Adjusted

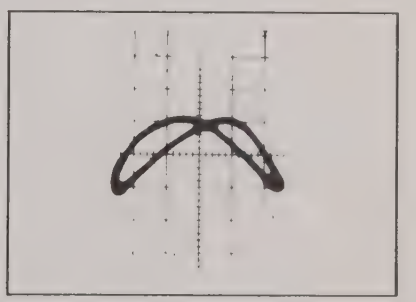


Fig. 5-5E P21 Maladjusted (2nd Harmonic In Notch)

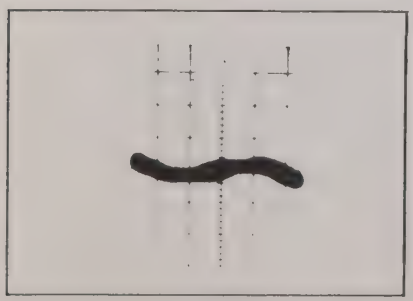


Fig. 5-5F P22 Maladjusted (3rd Harmonic In Notch)

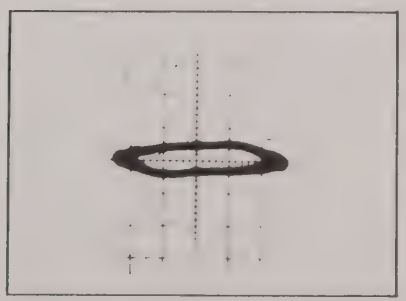


Fig. 5-5G P24 Maladjusted (2nd Harmonic In Notch)

PHASE ERROR

Figure 5-5 VCO Adjustment, Oscilloscope Displays

f. P22, the 3rd Harmonic Adjustment, is set for minimum 3rd harmonic content in the notched-noise output. Adjust P22 to reduce even further the previous minimum on the CRO vertical display. This should be less than 2 mV. (Note that P22 affects the sine and cosine tone levels as well as one phase of 3rd harmonic. If P22 is turned, P36 on the Harmonic Analyzer board must be readjusted).

g. Readjust P24 and P25 as required, and then repeat steps c. through g. until the vertical deflections of the Lissajous figures cannot be reduced further. The foregoing procedure should give a 50 to 55 dB notch at all frequencies.

5-25. ADJUSTMENT OF VCO OPEN-LOOP FREQUENCIES

a. On Figure 5-3, PPLL board, locate P15, P16, P17, P18, P19, and P20, the VCO Open-Loop Frequency Adjustments.

b. Set Oscillator #1 to 404 Hz, 0 dBm, and patch output into PB-1 input jacks.

c. Set PB-1 input termination switch to 600Ω, LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 400 Hz, OUTPUT SELECT switch to TONE (this opens the VCO loop and makes the VCO a free-running oscillator), and MODE switch to FREQ DEV, %/10.

d. PB-1 CRT vertical deflection should be zero (spot should be on graticule vertical center line near horizontal center line). Set P15, the VCO 404 Hz Open-Loop Frequency Adjustment, so that CRT vertical deflection is zero, indicating that the frequency deviation is zero.

e. Set Oscillator #1 to 804 Hz, PB-1 NOMINAL FREQUENCY switch to 800, and set P16, the VCO 804 Hz Open-Loop Frequency Adjustment, so that frequency deviation is zero, as indicated by zero vertical deflection.

f. Set Oscillator #1 to 1004 Hz, PB-1 NOMINAL FREQUENCY switch to 1000, and set P17, the VCO 1004 Hz Open-Loop Frequency Adjustment, for zero frequency deviation.

g. Set Oscillator #1 to 1704 Hz, PB-1 NOMINAL FREQUENCY switch to 1700, and set P18, the VCO 1704 Hz Open-Loop Frequency Adjustment, for zero frequency deviation.

5-27. HORIZONTAL AND VERTICAL GAIN EQUALIZATION

a. On Figure 5-1, Rear Board, locate Potentiometers P3, P4, and P5.

b. After 10-minute warmup of PB-1, set MODE switch to VECTOR NOTCH, and JITTER DISPLAY switch to ZERO. Adjust HOR ZEROING potentiometer P3 so that CRT spot is centered horizontally, and adjust VERT ZEROING potentiometer P4 so that spot is centered vertically.

c. Set Oscillator #1 to 1004 Hz, 0 dBm; set Oscillator #2 to 2009 Hz, -12 dBm; patch both oscillator outputs into PB-1 input jacks.

d. Set PB-1 input termination switch to appropriate setting (see Par. 5-3), MODE switch to 2ND H, NOMINAL FREQUENCY switch to 1000 Hz, and SCALE switch to X5.

e. The CRT spot should revolve in a circular path at a rate equal to the difference in frequency of 2009 Hz - 2(1004) Hz = 1 Hz. If the length of the horizontal axis of the circular path is not equal to the length of the vertical axis, adjust P5 so that the two axes are of equal length, and the path of the spot is the best circle possible.

f. If the difference frequency of 2009 Hz - 2(1004) Hz exceeds 1 Hz, the spot will revolve more rapidly, and the diameter of the circular path will shrink because of attenuation by the low-pass filter in the detector circuits. Adjust one oscillator slightly so that the difference frequency becomes low enough to provide a circle of maximum diameter. This maximum circle path should coincide with the -12 dBm circle of the graticule. If the maximum circle path does not coincide with the -12 dBm graticule circle, do not change any settings or connections, but perform the adjustment described in Par. 5-31.

5-28. 2ND AND 3RD HARMONIC GAIN ADJUSTMENT

a. On Figure 5-4, Harmonic Analyzer Board, locate P36.

b. With Oscillators #1 and #2 set and connected to provide a difference-frequency circle of maximum diameter, as in Par. 5-27, adjust P36 to make the circle coincide with the -12 dBm circle on the graticule.

c. Reset Oscillator #2 to 3013 Hz, -12 dBm.

d. Reset PB-1 MODE switch to 3RD H.

e. The CRT spot should revolve around the -12 dBm graticule circle at a difference frequency of 3013 Hz - 3(1004) Hz = 1 Hz. Observe the equality of horizontal and vertical axes, and the size of the circle, but do not readjust P36.

5-29. NNN Cos wt MULTIPLIER BALANCE ADJUSTMENTS

a. On Figure 5-2, IAGC Board, locate Potentiometers P10 and P11.

b. Set Oscillator #1 to 1004 Hz, 0 dBm; set Oscillator #2 to 1200 Hz, -12 dBm; patch both outputs into PB-1 input jacks.

c. Set PB-1 input termination switch appropriately (see Par 5-3), LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, MODE switch to VECTOR NOTCH, and FILTER RANGE switch to UNFILTERED.

d. The PB-1 display will be a disc pattern for SFI frequencies not near 1004 Hz and not harmonically related to 1004 Hz. The pattern should appear as two almost coincident discs slightly displaced. Adjust P11 and P10 alternately to achieve the best vertical coincidence of the two discs.

5-30. NNN SIN wt MULTIPLIER BALANCE ADJUSTMENTS

a. On Figure 5-3, PPLL Board, locate P32, P33, P34. Potentiometer P32 is the NNN Sin wt DC Balance Adjustment; P33 and P34 are the NNN Sin wt Multiplier #1 and #2 Balance Adjustments, respectively.

b. Set Oscillator #1 to 1004 Hz, 0 dBm, and patch output into PB-1 input terminals.

c. Set PB-1 input termination switch to 600Ω, MODE switch to VECTOR NOTCH, FILTER RANGE switch to UNFILTERED, LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, OUTPUT SELECT switch to NOTCHED NOISE, and SCALE switch to X0.5.

d. Pin E of the PB-1 rear output connector is the output of the NNN Sin wt Multiplier, and Pin K is circuit ground. Connect the voltmeter across Pins E and K, and adjust P32 so that voltmeter indication is within 0 ± 0.25 VDC. Disconnect voltmeter.

e. Adjust P33 for minimum horizontal deflection on the CRT.

f. Leaving Oscillator #1 set to 1004 Hz, 0 dBm, set Oscillator #2 to 1200 Hz, -12 dBm (25% of Oscillator #1 output level), and patch Oacillator #2 output into PB-1 input jacks as an SFI tone. Set PB-1 input termination switch appropriately (See Par. 5-3).

g. The CRT should display a disc pattern for SFI frequencies not near 1004 Hz and not harmonically related to 1004 Hz. The pattern may appear as two superimposed discs that are slightly offset from each other. Adjust P33 and P34 for minimum horizontal offset.

5-31. VECTOR NOTCH GAINS, UNFILTERED

a. On Figure 5-2, IAGC Board, locate P9; and on Figure 5-3, PPLL Board, locate P35. Potentiometer P9 is the NNN Cos wt Multiplier Coarse (DC) Balance Adjustment; it affects the vertical deflection sensitivity in the VECTOR NOTCH mode, and also the AGC loop gain. P35 is the NNN Sin wt Gain Adjustment; it affects the horizontal deflection sensitivity in the VECTOR NOTCH mode.

b. Set Oscillator #1 to 1004 Hz, 0 dBm; set Oscillator #2 to 1200 Hz, -12 dBm (25% of Oscillator #1 output level); patch both outputs into PB-1 input jacks.

c. Set PB-1 input termination switch appropriately (see Par. 5-3), LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, MODE switch to VECTOR NOTCH, FILTER RANGE switch to UNFILTERED, JITTER DISPLAY switch to VECTOR, and SCALE switch to X1.

d. The CRT display will be the typical SFI disc that appears when the SFI frequency is neither near nor harmonically related to the primary tone. Adjust P9 to make the vertical diameter of the disc coincide with the vertical diameter of the -12 dBm circle on the graticule, and adjust P35 to make the horizontal diameter of the disc coincide with the horizontal diameter of the -12 dBm graticule circle. The edges of the disc should now coincide with the -12 dBm graticule circle.

5-32. VECTOR NOTCH GAINS, 20-300 HZ FILTERS

a. On Figure 5-4, Harmonic Analyzer Board, locate Potentiometers P40 and P41. Potentiometer P40 is the 20-300 Hz Vertical Filter Gain Adjustment, and P41 is the 20-300 Hz Horizontal Filter Gain Adjustment.

b. Set Oscillator #1 to 1004 Hz, 0 dBm; set Oscillator #2 to 1200 Hz, -12 dBm (25% of Oscillator #1 output level); patch both outputs into PB-1 input jacks.

c. Set PB-1 input termination switch appropriately (see Par. 5-3), LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, MODE switch to VECTOR NOTCH, FILTER RANGE switch to 20-300 Hz, JITTER DISPLAY switch to VECTOR, and SCALE switch to X1.

d. The CRT display will be the typical SFI disc that appears when the SFI frequency is neither near, nor harmonically related to, the primary tone. Adjust P40 to make the vertical diameter of the disc coincide with the vertical diameter of the -12 dBm circle on the graticule, and adjust P41 to make the horizontal diameter of the disc coincide with the horizontal diameter of the -12 dBm graticule circle. The edges of the disc should now coincide with the -12 dBm graticule circle.

e. Vary Oscillator #2 frequency over the ranges (704 to 984) Hz and (1024 to 1304) Hz, which correspond to the sidebands of 1004 ±(20 to 300) Hz. The disc should have a constant -12 dBm diameter within the sidebands. Outside the sidebands, i.e., below 704 Hz, between 984 and 1024 Hz, and above 1304 Hz, the disc diameter should decrease markedly.

5-33. VECTOR NOTCH GAINS, 20-600 HZ FILTERS

a. On Figure 5-4, Harmonic Analyzer Board, locate Potentiometers P38 and P39. Potentiometer P38 is the 20-600 Hz Vertical Filter Gain Adjustment, and P39 is the 20-600 Hz Horizontal Filter Gain Adjustment.

b. Set Oscillator #1 to 1004 Hz, 0 dBm; set Oscillator #2 to 1200 Hz, -12 dBm (25% of Oscillator #1 output level); patch both outputs into PB-1 input jacks.

c. Set PB-1 input termination switch appropriately (see Par. 5-3), LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, MODE switch to VECTOR NOTCH, FILTER RANGE switch to 20-600 Hz, JITTER DISPLAY switch to VECTOR, and SCALE switch to X1.

d. The CRT display will be the typical SFI disc that appears when the SFI frequency is neither near, nor harmonically related to, the primary tone. Adjust P38 and P39 so that the edges of the SFI disc coincide with the -12 dBm graticule circle.

e. Vary Oscillator #2 over the ranges (404 to 984)Hz and (1024 to 1064)Hz, which are the lower and upper sidebands of 1004 ± (20 to 600)Hz. The disc should have a constant -12 dBm diameter within the sidebands. Outside the sidebands; i.e., below 404 Hz, between 984 and 1024 Hz and above 1604 Hz, the disc diameter should decrease markedly.

5-34. AGC GAIN ADJUSTMENT

a. On Figure 5-2, IAGC Board, locate P14, the AGC Loop Gain Adjustment.

b. Set Oscillator #1 to 1004 Hz, 0 dBm; set Oscillator #2 to 980 Hz, -20 dBm (10% of Oscillator #1 output level); patch both outputs into PB-1 input jacks.

c. Set PB-1 input termination switch to BRIDGE, LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, MODE switch to VECTOR NOTCH, FILTER RANGE switch to 20-300 Hz, JITTER DISPLAY switch to VECTOR, and SCALE switch to X2.

d. Vary Oscillator #2 frequency from 984 Hz to 1024 Hz; i.e., 1004 ± 20 Hz. Set P14 for the best circle as the difference between 1004 Hz primary tone and SFI frequency approaches zero.

5-35. AGC LEVEL ADJUSTMENT

a. On Figure 5-2, IAGC Board, locate P12 and P13. Potentiometer P12 is the dBm LEVEL Calibration Adjustment; it affects the vertical gain in the dBm LEVEL mode, as well as the range of levels (approximately ±4.5dB) within which the DO NOT READ lamp is off. Potentiometer P13 is the AGC Voltage Zero Level Adjustment; it sets the CRT zero vertical deflection point in the dBm LEVEL mode.

b. Set Oscillator #1 to 1004 Hz ± 0.2%, 0 dBm, and patch output into PB-1 input jacks.

c. Set PB-1 input termination switch to 600Ω, LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, MODE switch to dBm LEVEL, and SCALE switch to X1. Adjust P13 for zero vertical deflection.

d. With Oscillator #1 at 1004 Hz, 0 dBm, increase output to +5 dBm and then decrease output to -5 dBm. Adjust P12 so that ± 5 dBm deflections match ±5 dBm graticule calibrations.

5-36. FREQUENCY DEVIATION CALIBRATION

a. On Figure 5-3, PPLL Board, locate P26, the FREQ DEV, %/10 Calibration Adjustment. Potentiometer P26 sets the vertical spot deflection versus frequency deviation to match the vertical percent calibrations on the graticule.

b. Set Oscillator #1 to 1004 Hz, 0 dBm, and patch output into PB-1 input jacks.

c. Set PB-1 input termination switch to 600Ω, NOMINAL FREQUENCY switch to 1000 Hz, LEVEL ADJ switch to 0 dBm, MODE switch to FREQ DEV, %/10, SCALE switch to X10.

d. Note the vertical deflection. This should be zero for the 1004 Hz input from Oscillator #1.

e. Set Oscillator #1 to 1004 Hz -6% = 944 Hz. The CRT spot should move vertically downwards to the -6% graticule calibration.

f. Set Oscillator #1 to 1004 Hz +6% = 1064 Hz. The CRT spot should move vertically upwards to the +6% graticule calibration.

g. Adjust P26 so that CRT spot deflections in steps e. and f. coincide with the ± 6% graticule calibrations.

h. The calibration should hold at the other operating frequencies: 404, 804, 1704, and 2804 Hz. For example, with the PB-1 NOMINAL FREQUENCY switch at 400, and Oscillator #1 set to 380 Hz (= 404 Hz -6%), 404 Hz, and 428 Hz (= 404 Hz + 6%), the spot deflections should be -6%, 0, and + 6% respectively.

5-37. PHASE-LOCK LOOP MULTIPLIER BALANCING

a. On Figure 5-3, PPLL Board, locate P28, P29, and Test Point C. Potentiometers P28 and P29 are the Phase-Lock Loop Multiplier #1 and #2 Adjustments. Test Point C is at the right end of Resistor R72, just above P23.

b. Set Oscillator #1 to 1004 Hz, 0 dBm, and patch output into PB-1 input jacks and also into CRO Horizontal input.

c. Connect CRO Vertical input across Test Point C and PB-1 ground, set CRO for Vectorscope operation so as to observe Lissajous figures, and adjust CRO H and V sensitivities as required.

d. Set PB-1 input termination switch to 600Ω, NOMINAL FREQUENCY switch to 1000, LEVEL ADJ switch to 0 dBm, OUTPUT SELECT switch to LOC. OSC.

e. Test Point C is at the output of the PLL Multiplier. The signal at Test Point C should be a pure tone of twice the input frequency when the PLL is locked to the input. Adjust P28 and P29 for pure 2008 Hz signal at Test Point C.

5-38. CALIBRATION OF NOTCHED-NOISE OUTPUT

a. On Figure 5-4, Harmonic Analyzer Board, locate P37, the Notched-Noise Output Gain Adjustment.

b. Set Oscillator #1 to 1004 Hz ± 0.2%, 0 dBm, set Oscillator #2 to 1200 Hz, -12 dBm (25% of 0 dBm test tone from Oscillator #1), and patch both outputs into PB-1 input jacks.

c. Connect Level Meter to PB-1 600Ω output jacks.

d. Set PB-1 input termination switch appropriately (see Par. 5-3), LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 1000 Hz, OUTPUT SELECT switch to NOTCHED NOISE, and OUTPUT LEVEL switch to 0.

e. Set P37 so that the Level Meter indicates -12 dBm (0.1939 VRMS).

5-39. PHASE-LOCK-LOOP MULTIPLIER GAIN ADJUSTMENT

a. On Figure 5-3, Precision Phase-Lock Loop Board, locate P23, the Phase-Lock-Loop Multiplier Gain Adjustment. The setting of P23 affects the PLL response time.

b. Set Oscillator #1 to 2804 Hz + 6% (= 2972 Hz), 0 dBm, and patch output into PB-1 input jacks.

c. Set PB-1 input termination switch to 600Ω, LEVEL ADJ switch to 0 dBm, NOMINAL FREQUENCY switch to 2800 Hz. Note if DO NOT READ lamp goes on.

d. Reset Oscillator #1 to 404 Hz - 6% (= 380), 0 dBm.

e. Set PB-1 NOMINAL FREQUENCY switch to 400 Hz. Note if DO NOT READ lamp goes on.

f. If DO NOT READ lamp went on in any of steps b. through e., reset P23 until DO NOT READ lamp remains off at both the highest operating frequency of 2972 Hz (= 2804 Hz + 6%) and the lowest operating frequency of 380 Hz (= 404 Hz - 6%).

OPERATION OF 2A/2B LINE SIMULATOR WITH PB-1 LINE ANALYZER

A-1. INITIAL SETUP OF 2A/2B AND PB-1

A-2. Setup of 2A/2B

a. Using power cable supplied with 2A, connect recessed male power receptacle at upper right corner of 2A panel to 115 VAC, 50/60 Hz source.

b. Into the 7-pin jack at the upper left corner of the 2A panel, insert the plug of the cable from the 2B, or (for 2A not furnished with 2B) a jumper plug.

c. Set: ON/OFF button to ON; all seven ON/OFF toggle switches to OFF; HIT INTERVAL toggle switch to PUSH TO HIT; SIGNAL SOURCE switch to TONE FREQUENCY; TONE FREQUENCY control to 1000 Hz; OUTPUT LEVEL controls to 0 dBm (either by setting OUTPUT LEVEL switch to -10 dBm and OUTPUT LEVEL vernier to +10 dBm, or by setting both switch and vernier to 0 dBm); SOURCE IMPEDANCE switch to 600Ω. The signal at the output jacks at the lower right hand corner of the 2A panel will be 1000 Hz, at 0 dBm, into a 600 ohm load.

d. Patch from 2A output into PB-1 input.

A-3. Setup of PB-1

a. Using the power cable supplied with PB-1, connect from recessed male power receptacle at bottom rear of PB-1 to 115 VAC, 50/60 Hz source.

b. Set: POWER switch to ON; FOCUS and INTENSITY controls at top of panel for finest CRT spot; SCALE ILLUM control for desired brightness of CRT graticule scales; input termination switch to 600Ω; NOMINAL FREQUENCY switch to 1000 Hz; OUTPUT SELECT switch to any position except TONE.

c. NOTE: to avoid burning center of screen, reduce setting of INTENSITY control if CRT spot remains undeflected for long periods.

d. Check CRT zero deflection positions by setting MODE switch to VECTOR NOTCH, SCALE switch to X0.5, and JITTER DISPLAY switch to ZERO. If CRT deflection is not zero, wait 10 minutes for full warmup, then set HOR AND VERT ZEROING adjustments at rear of PB-1 for CRT zero deflection. Reset JITTER DISPLAY switch to VECTOR.

A-4. SETTING AND MEASURING QUIET-TONE FREQUENCIES

a. When the PB-1 MODE switch is set to FREQ DEV %/10, and the SCALE switch is set to X10, the vertical deflection is equal to the percent deviation, 100 $\Delta f/f$, of the input quiet-tone frequency from any one of the center frequencies (404, 804, 1004, 1704 or 2804 Hz, or the optional frequency f6) selected by the NOMINAL FREQUENCY switch. The measurement can be made over a $\pm 8\%$ range about each center frequency, with an accuracy of $\pm 0.25\%$.

b. On the PB-1: set MODE switch to FREQ DEV %/10; set SCALE switch to X10; check that DO NOT READ lamp is off.

c. Read vertical deflection. If 2A TONE FREQUENCY control is set to 1004 Hz exactly, the PB-1 vertical deflection will be zero ($\pm 0.25\%$), indicating zero frequency deviation.

d. Slowly vary the 2A TONE FREQUENCY control over $\pm 6\%$ from 1004 Hz, and note the corresponding PB-1 vertical deflections in percent frequency deviation.

e. Slowly raise 2A TONE FREQUENCY until DO NOT READ lamp goes on and remains on. This frequency should be greater than 1004 Hz +8%. Slowly lower 2A TONE FREQUENCY below 1004 Hz. DO NOT READ lamp will go on again and remain on when frequency is lower than 1004 Hz -8%. The PB-1 is thus seen to remain locked to any frequency within the range 1004 Hz $\pm 8\%$. The PB-1 will also remain locked over a $\pm 8\%$ range about any other center frequency selected by the NOMINAL FREQUENCY switch.

f. Perform steps d. and e. at 404 Hz and at 2804 Hz.

g. Reset 2A TONE FREQUENCY control to 1004 Hz (zero frequency deviation).

A-5. SETTING AND MEASURING QUIET-TONE LEVELS

a. When the PB-1 MODE switch is set to LEVEL dBm, and the SCALE switch is set to X1, the dBm level of a correctly-terminated input signal is the sum of the vertical deflection and the LEVEL ADJ switch setting (when the LEVEL ADJ switch is set so that the DO NOT READ lamp is off). At other SCALE switch settings, the dBm level of a correctly-terminated input signal (when the LEVEL ADJ switch is set so that DO NOT READ lamp is off) is given by: (LEVEL ADJ setting) + (SCALE switch setting) (vertical deflection).

b. Set PB-1 controls as follows: LEVEL ADJ switch to 0 dBm; MODE switch to LEVEL, dBm; SCALE switch to X1. The DO NOT READ lamp should be off, and the CRT vertical deflection should be zero, since the input from the 2A is 0 dBm, and the LEVEL ADJ setting is 0 dBm.

c. Pull patch cord from PB-1 input and observe that CRT spot deflects downward and that DO NOT READ lamp goes on. Reinsert patch cord into input and observe that DO NOT READ lamp goes on and that CRT deflection returns to zero.

d. Slowly increase 2A OUTPUT LEVEL setting, noting corresponding upward deflection, until DO NOT READ lamp goes on. This should be at some level between +4.5 and +5.5 dBm. Slowly decrease 2A OUTPUT LEVEL setting, noting corresponding downward deflection, until DO NOT READ lamp goes on again. This should be at some level between -4.5 and -5.5 dBm. Thus the DO NOT READ lamp is off for all input levels withing $\pm$ 4.5 dB of the input level for zero deflection, and is on for all inputs more than $\pm$ 5.5 dB fron the input level for zero deflection. Reset 2A OUTPUT LEVEL to 0 dBm.

e. Set PB-1 LEVEL ADJ switch to -5 dBm. CRT spot should move up to +5 dB. Set LEVEL ADJ switch to +5 dBm. CRT spot should move down to -5 dBm. Reset LEVEL ADJ switch to 0 dBm.

f. Set 2A OUTPUT LEVEL to +1 dBm, and observe PB-1 deflection. This should be approximately +1 major vertical division. Repeat with SCALE switch settings of X0.5 and X2. The corresponding deflections should be 2 and ½ major vertical divisions, respectively.

g. Turn PB-1 SPEAKER VOLUME up, set SPEAKER switch to INPUT, and listen to INPUT tone. Set SPEAKER switch to NOTCH and listen to input with tone notched out. Audible signals in this condition are caused by imperfections in the 2A tone oscillator. Usually the most audible components are the harmonics. Some commercially available oscillators have significant amounts of phase jitter and/or amplitude jitter. There is almost always some additive 60 Hz on line-powered oscillators but this will be inaudible unless it is excessive because it reaches the speaker at 60 Hz where, like all small speakers, the PB-1 speaker response is down. The 60 Hz on the input can be viewed in other PB-1 modes.

h. Set the PB-1 SPEAKER switch to NOTCH, and increase the VOLUME so that disturbances are audible. Set NOISE level at 60 dBrn and LEVEL ADJ to -10 dBm. Observe that DO NOT READ light comes on, and that speaker output is reduced. The speaker gain is deliberately reduced in the NOTCH position when the DO NOT READ light is on, to prevent the possibility of someone, who is listening closely to a tone which is interrupted, from suffering a case of ringing ears. When the tone is interrupted, the notched noise becomes the PB-1 local oscillator at reference level.

i. Set PB-1 SPEAKER switch to INPUT. Set LEVEL ADJ to -30 dBm. The speaker is now monitoring the input independently of the PB-1 AGC and Phase-Lock Loop. Adjust the SPEAKER VOLUME as desired. This is the operating condition to use when attempting to establish whether or not a tone is present on a line.

A-6. MEASURING DISTURBANCES IN THE PB-1 LEVEL MODE

a. In the LEVEL mode, the PB-1 functions as a level meter with a narrowband filter. This is not a primary measuring mode of the PB-1, but it is sometimes useful for observing certain low-frequency disturbances. The following steps show how to use the PB-1 in the LEVEL mode to measure various disturbances.

b. Background Noise

1. Check that 2A output is 1000 Hz, 0 dBm, at 600Ω.
2. Set 2A NOISE LEVEL controls for 60 dBrn of noise (ON/OFF switch to ON, attenuator switch to 60 dBrn, and vernier to 0 dBrn). Since 0 dBrn = -90 dBm, 60 dBrn = -30 dBm of noise. Since the OUTPUT LEVEL is 0 dBm, this corresponds to a 30 dB signal to noise ratio.
3. Set the PB-1 SCALE switch to X0.5 and observe the extent of the erratic vertical motion caused by this level of noise.
4. Increase 2A NOISE LEVEL by ± 10 dB and observe deflection on PB-1.
5. Reset 2A NOISE LEVEL to 60 dBrn, and set NOISE LEVEL ON/OFF switch to OFF.

c. Amplitude Modulation.

1. Set 2A AMPLITUDE MODULATION ON/OFF switch to ON.
2. Set 2A AMPLITUDE MODULATION control to 6%.
3. Set 2A MODULATION FREQUENCY range switch to X0.1.
4. Slowly vary MODULATION FREQUENCY control from 1 Hz to 30 Hz. On PB-1, observe 1 dB vertical variation (± ½ dB = ± 6%).
5. Set 2A MODULATION FREQUENCY range switch to X1.
6. Slowly vary MODULATION FREQUENCY control from 10 Hz to 300 Hz. On PB-1, observe that vertical variation becomes zero above about 50 Hz.

d. Amplitude Modulation and Noise.

1. Set 2A NOISE LEVEL ON/OFF switch to ON.
2. Repeat steps c.1. through c.4. above. On PB-1, observe vertical deflection with combined AM and noise.
3. Set 2A NOISE LEVEL ON/OFF switch to OFF.
4. Set 2A AMPLITUDE MODULATION ON/OFF switch to OFF.

e. Gain Hits

1. Set 2A GAIN HIT ON/OFF switch to ON.
2. Set 2A GIN HIT AMPL control to 2 dB.
3. Set 2A HIT INTERVAL toggle switch to PUSH TO HIT.
4. Set 2A HIT RISE TIME to 5 milliseconds (range switch to X1, control to 5).
5. Set 2A HIT DURATION to 1000 milliseconds (range switch to X10, control to 100).
6. Depress and release PUSH TO HIT button. On PB-1, observe 2 dB vertical deflection corresponding to 5 milliseconds rise time gain hit. Note that deflection returns to zero only after 1000 millisecond HIT DURATION.
7. Set 2A HIT RISE TIME to 200 milliseconds (range switch to X10, control to 20).
8. Depress and release PUSH TO HIT button. On PB-1, observe 2 dB vertical deflection corresponding to 200 millisecond rise time gain hit.
9. Set GAIN HIT ON/OFF switch to OFF.

A-7. USING PB-1 ACOUSTIC OUTPUT

a. The PB-1 SPEAKER output is an extremely useful auxiliary to the visual display. In the INPUT position, it permits a rapid check for the presence of an input signal, when there is no display. In the NOTCH position , it presents the audible equivalent of the Normalized Notched Noise seen on the PB-1 display when the MODE switch is set to VECTOR NOTCH. Correlation of visual and acoustic outputs frequently permit identification of telephone transmission facilities through which the test tone may pass.

b. Set PB-1 SPEAKER switch to INPUT, turn SPEAKER VOLUME up to satisfactory level, and listen to input. This is the PB-1 input signal at the arm of the LEVEL ADJ switch, before it is automatically gain controlled.

c. Set PB-1 SPEAKER switch to NOTCH, and listen to the automatically gain-controlled input signal with quiet tone notched out, or Normalized Notched Noise (NNN).

d. Note: Ideally, if the 2A output were a pure sinusoidal tone, the NOTCH audio output would be inaudible. Any audible NOTCH output is caused by imperfections, mainly harmonics, in the 2A tone oscillator. Some commercially-available tone oscillators have not only significant amounts of harmonic content, but also phase jitter and/or amplitude jitter, and (on oscillators operating from AC power sources) some additive

power line fundamental. 50 or 60 Hz power-line fundamentals and lower harmonics will be inaudible because the PB-1 speaker response, like that of all small speakers, falls off below 200-300 Hz. However, any power frequency components present in the PB-1 input signal will be visible in one or more display modes.

A-8. MEASURING DISTURBANCES IN PB-1 VECTOR NOTCH MODE

a. Amplitude Modulation.

1. Set PB-1 MODE switch to VECTOR NOTCH, SCALE switch to X5, JITTER DISPLAY switch to VECTOR, FILTER RANGE switch to 20 to 300, SPEAKER switch to NOTCH.

2. Set 2A TONE FREQUENCY to 1000 Hz, SIGNAL SOURCE switch to TONE FREQUENCY, AMPLITUDE MODULATION ON/OFF switch to ON, AMPLITUDE MODULATION control to 10%.

3. With 2A MODULATION FREQUENCY range switch set to X0.1, X1, and X10, vary MODULATION FREQUENCY control over ranges of 1 to 30 Hz, 10 to 300 Hz, and 100 to 3000 Hz respectively. Observe that vertical deflection is ± 10% (± 2% X5) within the 20 to 300 Hz FILTER RANGE, and falls off rapidly below 20 Hz and above 300 Hz. Note that the AM sidebands are audible, that they are at the MODULATION FREQUENCY, and that they do not fall off below 20 Hz or above 300 Hz. The FILTER RANGE switch is thus seen to control the bandwidth of the PB-1 visual display, but not that of the acoustic output.

4. Set 2A MODULATION FREQUENCY to 250 Hz, and slowly vary AMPLITUDE MODULATION control from 10% to 20%, and then to 0%, while observing PB-1 display and listening to PB-1 acoustic output. Vertical deflection and loudness of acoustic output should vary proportionally to % AMPLITUDE MODULATION. Reset AMPLITUDE MODULATION control to 10%.

5. Vary PB-1 SCALE switch settings and observe effect on display. Reset SCALE switch to X5.

6. Set PB-1 FILTER RANGE switch to 20 to 600 Hz, and observe the characteristics of this filter on the PB-1 display as the 2A MODULATION FREQUENCY is varied from 1 to 3000 Hz. at the 10% modulation level.

7. Set PB-1 FILTER RANGE switch to UNFILTERED, and observe the PB-1 display and listen to the acoustic output as the 2A MODULATION FREQUENCY is varied from 1 to 3000 Hz at the 10% modulation level.

b. Phase Modulation.

1. Check that PB-1 MODE switch is at VECTOR NOTCH, SCALE switch at X5, JITTER DISPLAY switch at VECTOR, FILTER RANGE switch at 20 to 300 Hz, SPEAKER switch at NOTCH.

2. Set 2A AMPLITUDE MODULATION ON/OFF switch to OFF, PHASE MODULATION ON/OFF switch to ON, MODULATION FREQUENCY to 100 Hz, PHASE MODULATION control to 10^{o}. Observe slightly curved horizontal deflection on PB-1 display, corresponding to the swing of the tip of the tone vector in response to the phase modulation.

3. Increase 2A MODULATION FREQUENCY to 200 Hz. Note that the curvature observed in step b.2. above disappears, because the second PM sideband (which is mainly responsible for the curvature) is now 400 Hz away from the tone frequency and is therefore outside the 300 Hz upper-frequency cutoff of the 20 to 300 Hz display filter.

4. Set the PB-1 FILTER RANGE switch to 20 to 600 Hz and observe the reappearance of the curvature in the display. Note in Steps 3 and 4 the acoustic output sounds like that for amplitude modulations. The only differences are in the phasing of the sidebands with respect to the tone, and the presence of a multiplicity of low-order sidebands. The ear can distinguish only the first sideband and cannot detect the difference between the phasing of AM sidebands and PM sidebands.

c. Single-Frequency Interference.

1. Set 2A PHASE MODULATION ON/OFF switch to OFF, SINGLE FREQUENCY INTERFERENCE ON/OFF switch to ON, SINGLE FREQUENCY INTERFERENCE control to 10%, MODULATION FREQUENCY to 1100 Hz, TONE FREQUENCY to 1000 Hz. Observe circular SFI pattern on PB-1 display.

2. Vary 2A MODULATION FREQUENCY over the range from 1 to 3000 Hz, and observe the display with PB-1 FILTER RANGE switch at 20-300 Hz. Note the narrow notch of $\pm$ 20 Hz around the tone frequency, and the roll-off at 300 Hz. Note that the single-tone acoustic output is not limited by the display filter.

3. Repeat step c.2. with PB-1 FILTER RANGE switch set to 20-600 Hz.

4. Repeat step c.2. with PB-1 FILTER RANGE switch set to UNFILTERED.

d. Noise.

1. Set 2A SINGLE-FREQUENCY INTERFERENCE ON/OFF switch to OFF, NOISE LEVEL ON/OFF switch to ON, NOISE LEVEL controls to 60 dBrn. On PB-1 display observe random noise pattern and acoustic output hiss.

2. Set PB-1 FILTER RANGE switch to 20-600 Hz and to 20-300 Hz and observe effects on display.

3. Set PB-1 JITTER DISPLAY switch to AMPLITUDE and observe effect on display.

4. Set JITTER DISPLAY switch to PHASE and observe effect on display. Reset JITTER DISPLAY switch to VECTOR.

A-9. MEASURING FOLDBACK PRODUCTS IN PB-1 VECTOR NOTCH MODE

a. In the case of amplitude modulation of a test tone, cos wt, by a sinusoidal signal, cos mt, the AM sidebands comprise the sum and difference frequencies of the test tone and the modulating tone. The difference frequency signal, cos (wt-mt), is zero when the tone and modulation frequency are equal. There are no negative frequencies; if the modulation frequency is greater than the tone frequency, the lower sideband does not become a negative frequency, but 'folds back' or reverses in sign. It thus appears at the positive frequency cos(mt-wt). For modulation at frequencies in the vicinity of twice the tone frequency, the lower sideband is in the vicinity of wt, i.e., cos (mt-wt) = cos(2wt-wt) = cos wt. The upper sideband is in the vicinity of the frequency 3wt. The lower sideband is then within the range of the filter (± 20 to ± 300 or ± 600 Hz around wt) and appears as an SFI tone. This situation is physically realizable in the communication network and is one source of apparent SFI tones. A similar kind of foldback or 'aliasing' occurs in sampled data systems with respect to the sampling frequency, e.g., 8KHz in typical T carrier type PCM systems. In this case, the foldback products appear at that frequency which is the difference between the sampling frequency and the frequency component in question.

b. On 2A, set SINGLE FREQUENCY INTERFERENCE ON/OFF switch to ON, SFI control to 20%, MODULATION FREQUENCY to 1700 Hz, and check that TONE FREQUENCY is 1000 Hz. On PB-1, listen for 700 Hz and 2700 Hz tones in acoustic output. Observe circular SFI display and note that SFI circle diameter is -20 dB. This is equivalent to 10% SFI, which is only half that of the SFI control setting. This is so because only one sideband is contributing to the visual display. This effect can also be achieved with phase modulation. In the case of phase modulation there is more than one sideband, and the second sideband may also be in the filter range. For example with 20% PM at 900 Hz on a 1000 Hz tone, the second sideband will appear at 800 Hz and thus describes a small SFI circle in the 20 to 300 Hz or 20 to 600 Hz FILTER RANGE position.

c. Turn off all impairments except NOISE. Set HIT INTERVAL toggle switch to HIT INTERVAL, set HIT INTERVAL to 1 second, HIT DURATION to 100 milliseconds, HIT RISE TIME to 2 milliseconds. Set PHASE HIT AMPL toggle switch to ON, and set PHASE HIT AMPL to 10^{o}. Observe effect on display (horizontal transient) and on acoustic output (pinging sound). Gradually reduce HIT INTERVAL. Note when the leading and trailing edge hits become acoustically indistinguishable. Return HIT INTERVAL to 300 milliseconds duration. Insert 10^{o} of phase jitter (PHASE MODULATION ON and at 10^{o}, MODULATION FREQUENCY at 100 Hz). Increase HIT RISE TIME gradually to 200 milliseconds. Observe tilt of display. This pattern when observed on a facility is an indication of slow phase hits (or small frequency shift transients).

d. Repeat above with GAIN HITS, starting at about 1 dB. Note vertical transient excursion and acoustic pinging.

e. Experiment with coincidence hits, i.e., simultaneous gain and phase hits, at various relative amplitudes.

f. Turn off gain and phase hits, set HIT DURATION to less than 100 milliseconds, HIT INTERVAL to 0.1 second, and IMPULSE hits at level of 80 dBrn. Observe random angular excursion of visual output and popping sound of acoustic output. Try the FILTER RANGE switch in all positions and note effect of bandwidth on visual display.

g. Turn off all 2A impairments except NOISE which is set at 60 dBrn. On 2B, set FREQUENCY TRANSLATION ON/OFF toggle switch to ON, and UP/DOWN toggle switch to UP. Set FREQUENCY TRANSLATION control to 3 Hz. After display has stabilized, reverse direction of frequency translation by setting UP/DOWN toggle switch to DOWN. Observe effect of 6 Hz frequency discontinuity or hit. Again wait until display has stabilized and reverse frequency shift direction. Set FREQUENCY TRANSLATION ON/OFF toggle switch to OFF.

A-10. MEASUREMENTS IN PB-1 HARMONIC MODES

a. Disconnect patch cord between 2A output and PB-1 input. Patch from 2A output to 2B INPUT FOR HARMONIC DISTORTION, and patch from either the -3 dBm or the -16 dBm output of the 2B to the PB-1 input. Note that the 2B output levels are correct only for 0 dBm input to 2B.

b. Set 2A TONE FREQUENCY to 1000 Hz, all impairment ON/OFF toggle switches to OFF, and OUTPUT LEVEL to 0 dBm. Set 2B FREQUENCY TRANSLATION, 2ND, and 3RD ON/OFF toggle switches to OFF. Set PB-1 MODE switch to 2ND H, SCALE switch to 0.5, and LEVEL ADJ switch so that DO NOT READ lamp is off. Observe the spot deflection; this is residual 2nd harmonic in the 2A TONE oscillator output.

c. Set 2B 2ND ON/OFF toggle switch to ON, and set SECOND HARMONIC control to 3%. (This corresponds to 2nd harmonic at 30 dB below tone level.) Set PB-1 SCALE switch so that spot is on screen. Set 2A NOISE LEVEL ON/OFF toggle switch to ON, and set NOISE LEVEL to 30 dB below tone. Observe display.

d. Turn on PHASE HITS at intervals of 2 seconds. Experiment with brief duration for rise time hits, say 3 milliseconds duration, 1/2 millisecond rise time. Experiment with slow rise time hits, say 500 millisecond duration, 50 to 200 millisecond rise time.

e. Turn off PHASE HITS, turn on FREQUENCY TRANSLATION. Set for 2 Hz. Observe effect on oscillator residual 2nd harmonic, which is introduced ahead of frequency translation. Observe effect on simulator-generated 2nd harmonic, which is introduced after the frequency translation. The multiplicity of harmonic sources in the simulator are all at voice band. This differs from a normal multiplexed channel where the only in-band distortion is that which occurs at the terminals.

f. Turn off all 2A/2B impairments. Turn on SFI at 10%. Vary modulation frequency in the vicinity of 2 HKz and observe, over a rather narrow frequency range, a circular pattern. If the frequencies are too close, the 2A/2B oscillator may cause hesitation or may lock onto each other,resulting in a stationary spot.

g. Turn off SFI. Turn on PHASE MODULATION at say 30%. Adjust MODULATION FREQUENCY to place 2nd PM sideband at 2 KHz; i.e., in the vicinity of 500 Hz for a 1000 Hz test tone. Observe display. Place first sideband at 2 KHz; i.e., vicinity of 1000 Hz. It will be necessary to change the SCALE switch setting or the PM amplitude to keep the spot on the screen.

h. Connect an external attenuator to the 2A TONE output, and patch the attenuator output into the 2B input. Using a level meter, adjust the attenuator for 0 dBm at the 2B input. If an oscilloscope is used instead of a level meter, a deflection of 2.2 volts peak to peak is equivalent to 0 dBm. Patch the 2B output to the EXT INPUT jack of the 2A. Set the 2A EXT INPUT/TONE switch to the EXT INPUT position. The harmonic distortion impairment generator of the 2B has now been patched ahead of the 2A. Repeat all 2nd harmonic, phase modulation and phase hits experiment above with the impairments occurring after the introduction of distortion. Note differences from previous condition.

i. Repeat steps b. through h. with PB-1 MODE switch set to 3RD H. In this case the frequency region of interest is 3 KHz, rather than 2 KHz. It may be necessary to lower the TONE FREQUENCY slightly to make sure that the MODULATION OSCILLATOR can reach the third harmonic of the tone.

ESTABLISHMENT OF PB-1 BASELINE CRITERIA FOR MONITORING TRANSMISSION FACILITY PERFORMANCE AND EVALUATING FACILITY/MODEM COMPATIBILITY

B-1. RATIONALE OF PROGRAM

B-2. This Appendix outlines a program, employing the Bradley Telcom 2A/2B VF Line Simulator and PB-1 VF Line Analyzer, to establish baseline criteria for 'normal' performance of transmission facilities, and to correlate the performance of a facility in the transmission of test tones with the performance of the same facility in the transmission of data. The resulting baseline criteria may be in the form of numbers defining an area on the PB-1 graticule, or of an overlay defining the same area. Once these baseline criteria have been established, they may be used to make go/no-go evaluations of the following:

a. Facility performance in terms of the established baseline criteria for 'normal' performance.

b. Facility compatibility with any type of Modem.

B-3. The program involves the following:

a. Characterizing the generic performance of modems by types, in accordance with their disturbance threshold sensitivity. Figure B-1 shows a test setup for such 'calibration' of modems.

b. Characterizing the generic performance of transmission facilities by types in accordance with the types and levels of disturbances they normally generate. Figure B-2 shows a test setup for such 'calibration' of facilities.

B-4. The result of the program is a catalog or library of:

a. PB-1 baseline criteria for normal performance of various types of facilities.

b. PB-1 baseline criteria for normal operation of various types of modems.

c. PB-1 baseline criteria for modem/facility compatibility. These baseline criteria permit rapid go/no-go evaluations, using standard test tones, to determine if given facilities are compatible with given modems.

B-5. ESTABLISHING MODEM BASELINE CRITERIA

a. Connect the 2A/2B and PB-1 to the Modem as shown in Figure B-1. The 2A/2B is set us so that (in the EXT position of the switch) the Modem is coupled through it, and is monitored by a Bit Error Rate Counter. The 2A/2B output is also monitored by a PB-1.

b. Slowly increase impairments, individually and in combination, until the Bit Error Rate Counter starts to count.

c. At the threshold of counting, set the switch to INT, sending a test tone through the impairment generator while observing the PB-1 display. The test tone suffers identical impairments to the modem signal. The magnitude of tone impairment which corresponds to the modem error threshold may thus be observed. Photographs can be taken or graticule overlays constructed for operator information purposes.

B-6. ESTABLISHING FACILITY BASELINE CRITERIA

a. Connect the test oscillator and PB-1 to the facility as shown in figure B-2.

b. Using the oscillator at the far end, send a test tone through the transmission facility, and monitor the received tone with the PB-1 at the near end.

c. Examine a sufficient number of representative facilities of each type to establish characteristic patterns and limits.

B-7. LINE MAINTENANCE

The maintenance operations required are:

a. Send a test tone through the facility.

b. Monitor the test tone with the PB-1 Line Analyzer.

c. Place the switches of the PB-1 in particular positions, as established during the facility or modem baseline criteria calibration procedures of Pars. B-5 and B-6, and observe the displays inside a given 'window'. The window is established during the test program for each modem type and for each facility type.

d. If the display is outside the window, the line is no-go, and the reason for this is indicated by the manner in which the trace goes outside the window.

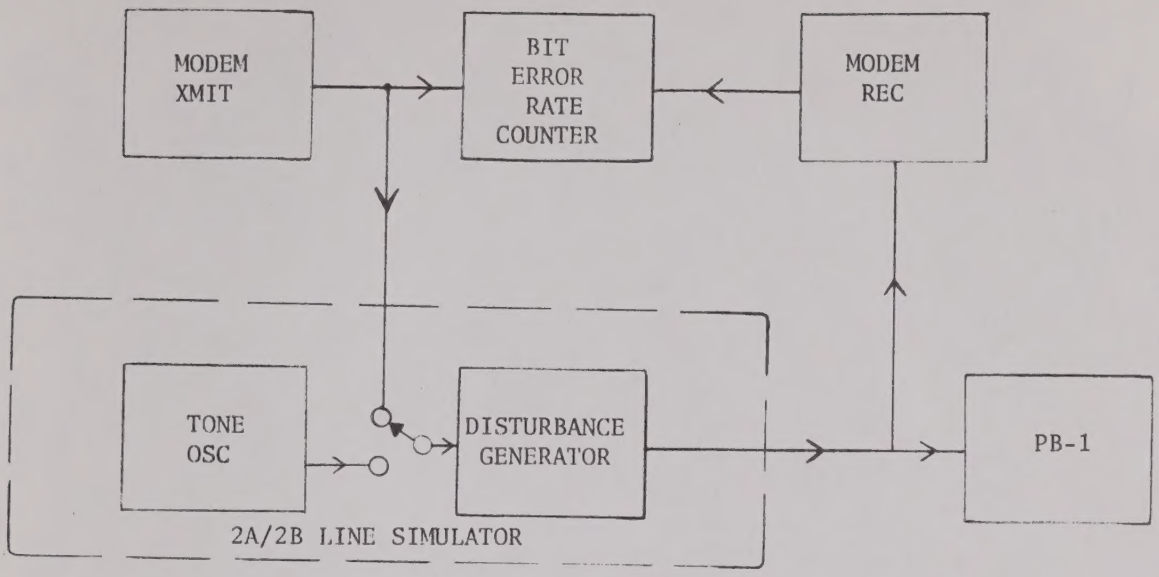


FIGURE B-1 Calibration of Modem Disturbance Threshold Sensitivity

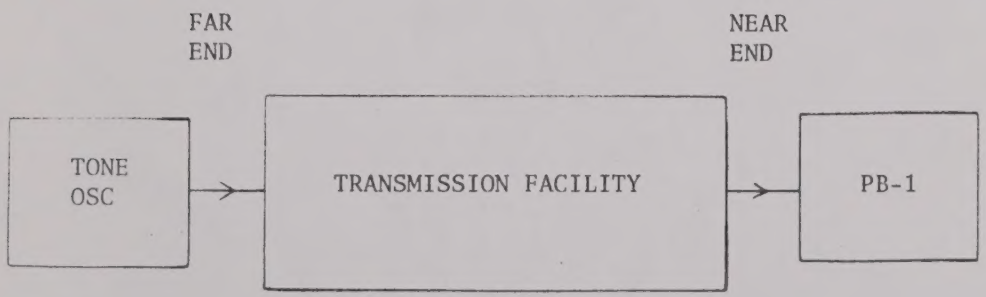
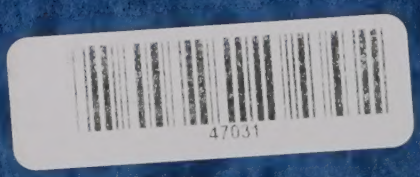


FIGURE B-2 Calibration of Transmission Facility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